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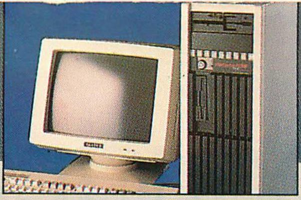


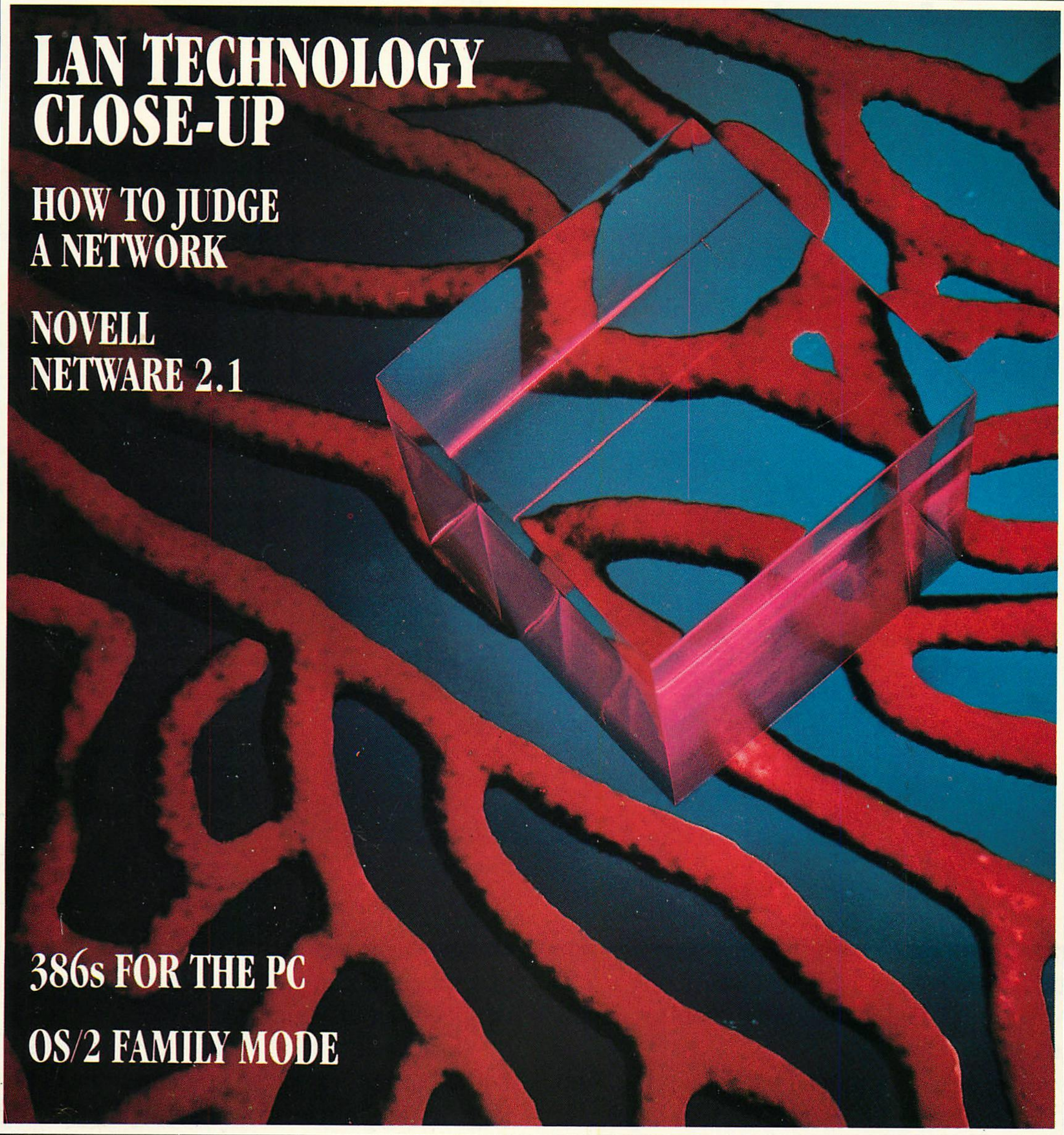
OPTIMIZING C CODE

JUNE 1988

VOL. 6 NO. 6 $3.95

PC TECH JOURNAL®

FOR SYSTEMS DEVELOPERS AND INTEGRATORS



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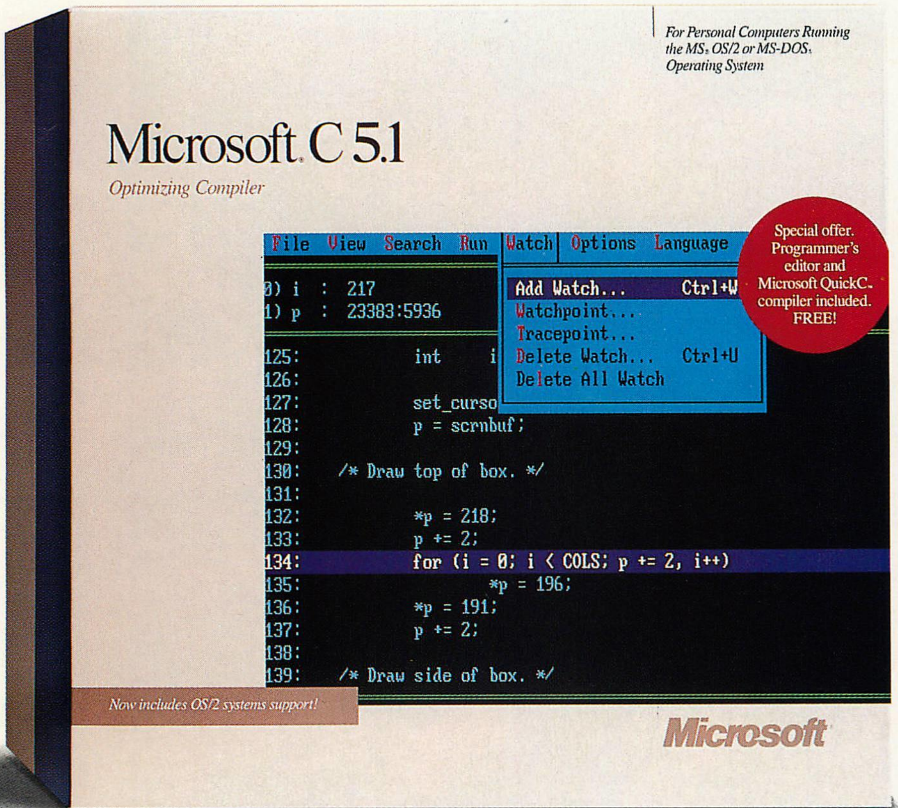

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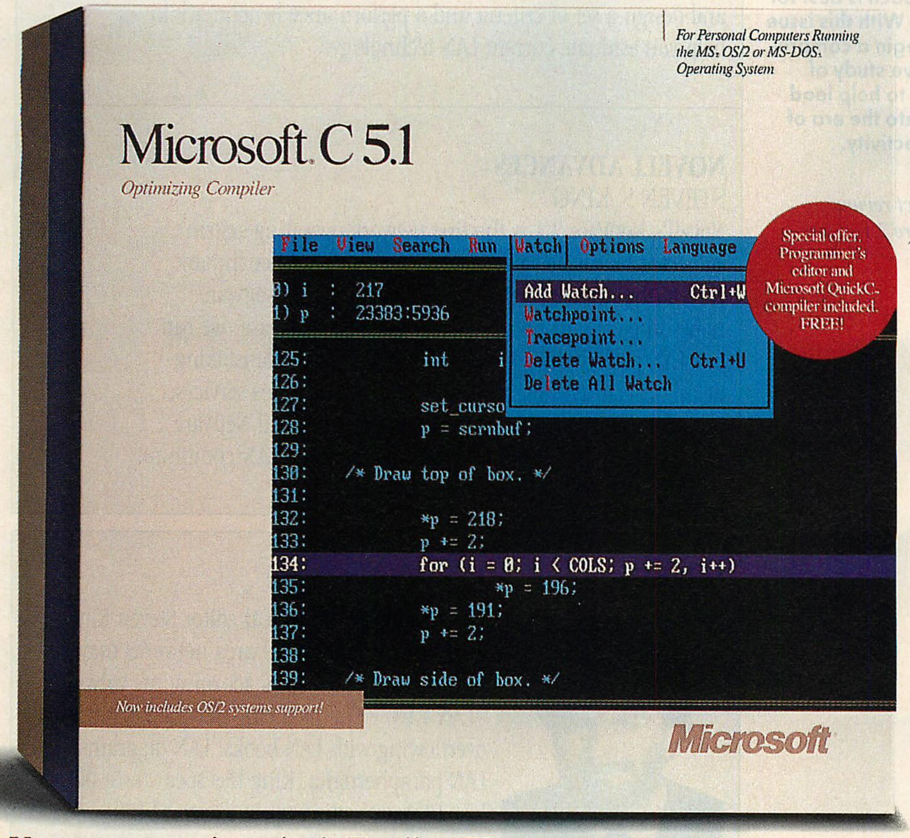

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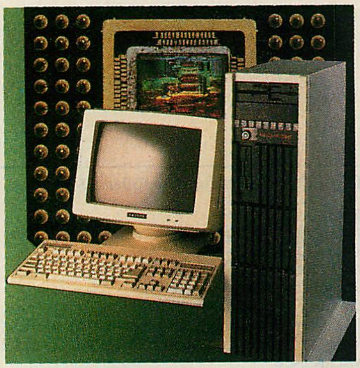
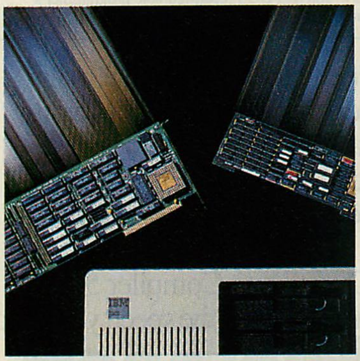


Industrial-Strength 386 100

Family Ties 124



The Souped-up PC 112

COVER SUITE: LAN TECHNOLOGY

The issues involved in implementing a local area network are becoming more complex all the time. Systems professionals need guidelines for deciding which approach is best for them. With this issue we begin a comprehensive study of LANs to help lead you into the era of connectivity.

NETWORK COMPLEXITY
STEVEN S. KING

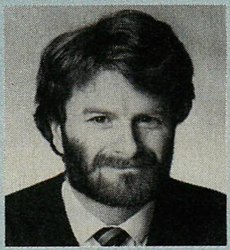
The old joke about the computer industry loving standards so much that it has hundreds of them is accentuated in the area of local area networks. Every aspect of networks can claim a number of "standards," so negotiating the path to LAN implementation can be treacherous. To help clear up the confusion, we identify the standards, sort through the issues, and design a set of criteria and a performance benchmark to help you evaluate current LAN technology. 44

Product review: NetWare 2.1

NOVELL ADVANCES
STEVEN S. KING

Novell's NetWare 2.1 is the first network operating system subjected to our new criteria and performance benchmark. Novell, the market leader in network operating software, hopes to bolster its position with this newest release. We run our LAN performance benchmark and look in painstaking detail at security; file, print, and communications services; protocols; and operating system internals to see if NetWare 2.1 can indeed solidify Novell's prominence in the LAN community. 58

LAN FAN



The first clue to technical editor Steven King's total dedication to local area networks may be the vanity license plates adorning his Volvo: "LAN FAN." The next clue may be his office, overflowing with LAN books, LAN diagrams, and LAN paraphernalia. King has spent most of the last 10 years setting up in excess of 100 networks for law firms, corporations, and the U.S. government. Since joining *PC Tech Journal* seven months ago, he has worked virtually nonstop, managing our own network and outfitting our testing facilities with the capability to evaluate LANs. For this month's cover suite, he spent countless hours conducting telephone interviews with the chief executive and technical officers of the major LAN vendors and was frequently found buried under documentation in his office or the lab. His extensive knowledge will give our continuing LAN coverage a solid foundation from which to grow.

VOLUME 6, NUMBER 6

APPLICATION DEVELOPMENT

Product reviews: Nine optimizing C compilers

HIGHLY POLISHED C CODE
PHILIP N. HISLEY

Developers are forever in search of ways to create faster code; most major C compiler vendors are trying to meet that need with optimization. We developed a benchmark to test a compiler's optimization capabilities and put the following products to the test: Borland's Turbo C, Computer Innovations' C86Plus, Datalight's Optimum C, Lattice's MS-DOS C, Manx's Aztec C86, Metaware's High C, Microsoft's C 5.0 and QuickC, and WATCOM's C 6.0. The results may surprise you. 76

COMPUTER SYSTEMS

Product review: ALR FlexCache 20386

INDUSTRIAL-STRENGTH 386
DAVID CLAIBORNE

The FlexCache 20386 from Advanced Logic Research aims for the power user who wants maximum hardware performance per dollar spent. With comparable performance to other 20-MHz 386 machines, the FlexCache 20386 comes in at a relatively lower price. Our compatibility and performance evaluation suite shows this to be a solid machine offering all the basics—but lacking some of the finishing touches. 100

Product reviews: PC-Elevator 386, Inboard 386/PC, Quad 386XT

THE SOUPED-UP PC
THOMAS V. HOFFMANN

Tired of that old 8088 processor? Feel like you're running in slow motion? PC and XT owners, there's hope: 386 add-in boards will breathe new life into sluggish machines. We go for a test drive in an XT with ARC's PC-Elevator 386, Intel's Inboard 386/PC, and Quadram's Quad 386XT. The results? It's not a genuine 386, but it certainly does move faster. 112

OPERATING ENVIRONMENTS

FAMILY TIES
DAVID SCHMITT

Microsoft knew well enough that it could not sever all ties to DOS when it developed OS/2. The connecting link is family mode, in which applications can run unchanged under either operating system. The sacrifices are that many of OS/2's finest features go unused. We give guidelines and sample code for developing family-mode applications. 124

DEPARTMENTS

9 **SYSTEMS PERSPECTIVE**
LAN Issues

15 **LETTERS**
Clarifying DRAM; comparing PS/2 prices.

25 **NEW DIRECTIONS**
Year of the User Interface

34 **TECH RELEASES**
Microsoft introduces enhanced languages; 3.5-inch hard-disk drives from Quantum; Microsoft and H-P announce LAN Manager/X; relational database from WordPerfect; and more.

139 **PRODUCT WATCH**
Triad Plus from Micronyx
WATCOM C 6.0

147 **TECH NOTEBOOK**
(1) Fixing a bug in QuickBASIC 4.0. (2) A surprise in the QB4 editor. (3) Tricky spaces in the DOS environment.

153 **OUTFITTING THE END USER**
Folklore, Fear—and Folly

160 **TECH MART**

164 **TECH MARKETPLACE**

174 **INDEX TO ADVERTISERS**

175 **INDEX TO PRODUCTS**

176 **PROFESSIONAL VIEWPOINT**
Saying it with pictures.

177 **READER SERVICE CARD**

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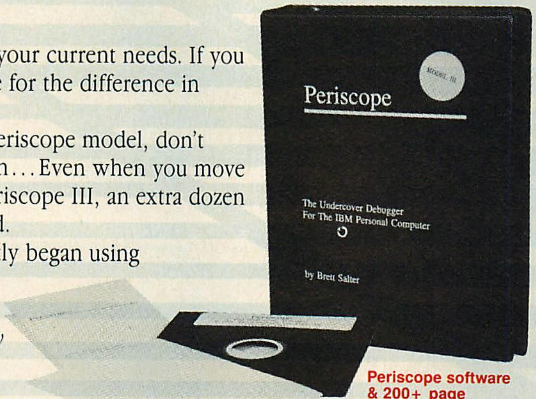

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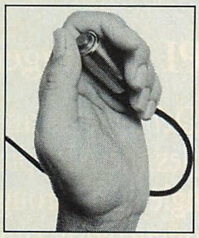
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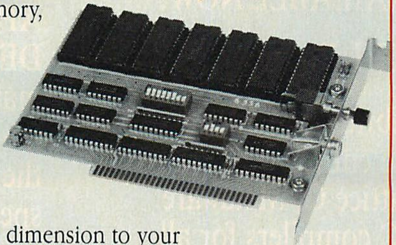
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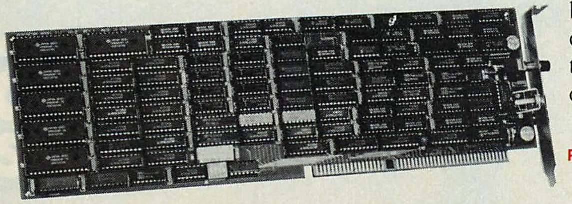
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SYSTEMS PERSPECTIVE

J Anderson

LAN Issues

Opportunity abounds. So do problems. But LANs are a direct route to the future of corporate computing.

Local area networks are the key to building multiuser systems, while still keeping personal computers personal. Unlike mainframes and minicomputers, a LAN allows us to share work-group and corporate data, printers, modems, and other resources without having to share a processor—and we are still able to maintain local data and applications.

Despite these differences, many of the same systems issues that apply to shared-processor multiuser systems apply to LANs—for example, system security, data integrity and reliability, user response time, electronic messaging, and resource use accounting. These are issues that should be familiar to most of you; we learned from our most recent subscriber study that 69 percent of our readers have an average of 10 years' experience working with mainframes, and 65 percent have an average of six years' experience working with minicomputers.

Besides understanding the problems that LANs must address, you can also appreciate the opportunities they open up for building sophisticated applications on personal computers. With the advent of database servers, LANs are fast becoming the enabling technology for distributed applications as well as distributed data.

Although the lower layers of the Open System Interconnection (OSI) model have stabilized, effective standards for the session and presentation layers are still evolving. Microsoft's OS/2 LAN Manager, which has gathered impressive support from industry vendors, may well answer these concerns. Still, many network operating systems and protocols may have to coexist for some time to come.

Network bridges and gateways are becoming more prevalent. Where 3270 emulation boards used to be installed in multiple PCs, a 3270 gateway is now being installed instead. In the future, corporations will be configured as networks of networks—and the problems will multiply.

In this month's cover suite, designed and written by our resident LAN expert, technical editor Steven S. King, we introduce a series of in-depth reviews of network operating systems. In the first article, "Network Complexity," (p. 44), King draws upon his 10 years of experience in designing, installing, and managing networks in order to analyze the current state of LAN technology and the directions in which it is likely to move in the future. He points out which network problems are adequately addressed by existing technology, and he reveals which areas still need standards.

King also introduces *PC Tech Journal*'s LAN performance benchmark. Like other multiuser systems, networks elude having their performance measured precisely. Each component of a network—the underlying topology, the server's and workstation's hardware (processor, bus, and disks), the network operating system, the number of active nodes, and even the applications being run by the end user—are contributing factors. Network performance at any moment, therefore, depends on how the LAN is configured and used.

Rather than trying to develop a single number that pegs a network's performance, the system administrator needs to construct a profile of the network's capabilities under different loads and with varying operating system parameters. This is exactly what the *PC Tech Journal* LAN performance benchmark does. Designed to measure end-to-end network throughput, the benchmark allows the system administrator to tune performance by varying the LAN's configuration.

In what we feel is the definitive reference on Novell's NetWare 2.1, ("Novell Advances," p. 58), King examines security; file, print, and communications services; client-server protocols; and operating system internals. Finally, he analyzes the results obtained from the LAN performance benchmark as run on NetWare 2.1.

OPTIMAL C

Performance is also an important consideration in choosing a C compiler. In February's Systems Perspective, I wrote that Microsoft C 5.0 produced the "best performing code of all the compilers we tested" in that month's "State of C" cover suite (p. 52). Peter Olcott of Omaha, Nebraska, took exception to my comment (see Letters, April 1988,

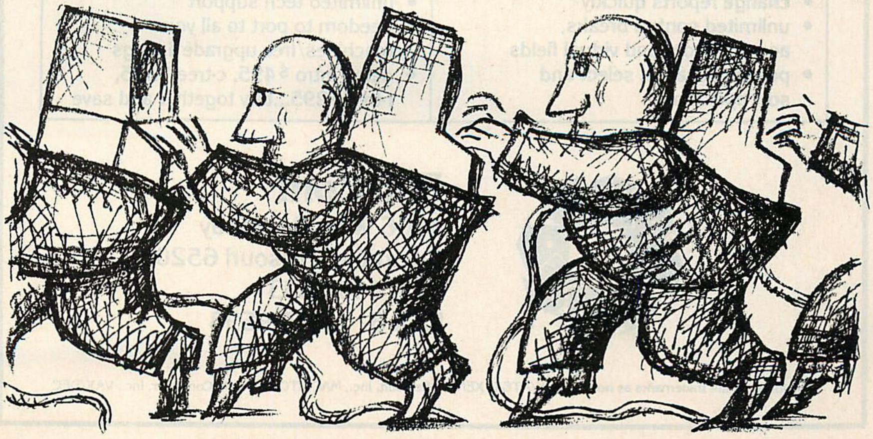

ILLUSTRATION • MACIEK ALBRECHT

p. 13), pointing out that the benchmarks we published did not support that statement. I answered that the benchmarks were run without full optimizations set. With optimizations on, Microsoft C 5.0 was the clear winner.

In response to that exchange, John Taylor of Fort Worth, Texas, wrote that I had spoken too soon. Taylor complained that I was announcing results of benchmarks that we had not yet run. In fact, we had run the benchmarks on the optimized versions of the code generated by C compilers; Mr. Taylor was correct, however, in claiming I had spoken too soon, as evidenced by this month's follow-up article, "Highly Polished C Code" (p. 76), by Philip N. Hisley.

Hisley examines the code generated by nine optimizing C compilers. He explains various optimization techniques of C compilers and publishes test source code he developed to exercise a compiler's ability to generate optimal code.

He also re-ran our performance benchmarks, with some amazing results. Newcomer WATCOM C 6.0 has taken over the coveted position of best optimizing compiler. In case you are wondering if you missed versions 1.0 through 5.0, don't fret. They were never sold. By numbering its first C compiler as version 6.0, WATCOM intends to establish its position as a worthy contender, deserving of its place among its mature competitors (see this month's Product Watch about WATCOM C on page 139).

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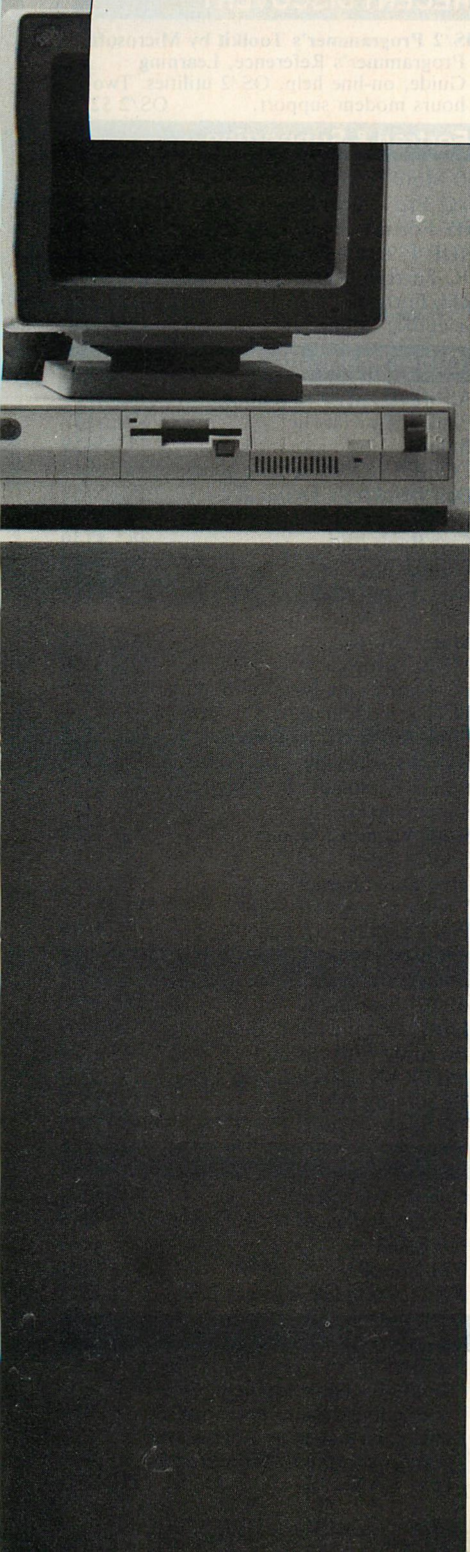

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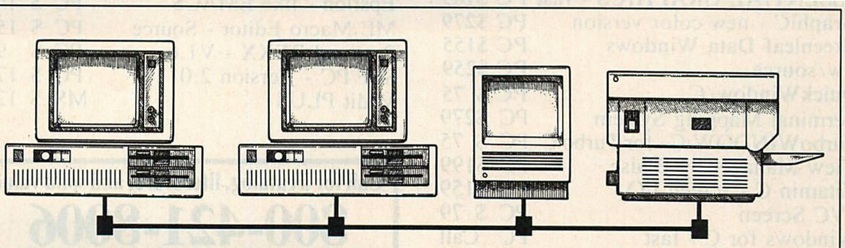

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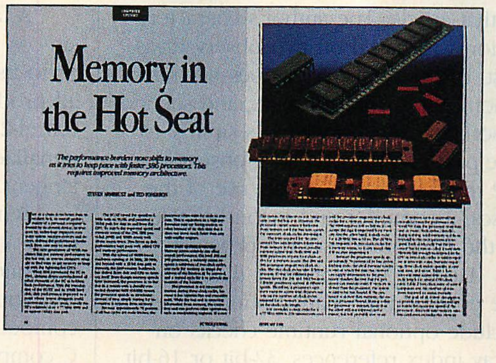
Memory in the Hot Seat


PS/2 Turns 1

TOO MUCH STATIC

Our compliments on the comprehensive article about memory configurations to support faster microprocessors ("Memory in the Hot Seat," Steven Armbrust and Ted Forgeron, February 1988, p. 84). However, we take issue with two points in the article: first, that dynamic RAM (DRAM) chips that are faster than 80 nanoseconds, or that can support zero-wait-state at 16 MHz or faster, are not "readily available;" second, that page mode and static-column mode are equivalent.

NMB Semiconductor Corporation has produced quantities of 60-, 70-, and 80-ns DRAM devices since early 1986. For the AAA280X-06, cycle time is 121 ns, supporting the 125-ns requirement cited by the authors. In fact, NMB does not sell DRAM devices with access times *slower* than 80 ns.

The confusing references to page mode and static-column mode seem to be because complementary metal-oxide semiconductor (CMOS) DRAM devices use static logic mechanization in column decoding. To our knowledge, all modern DRAM devices—N-channel MOS and CMOS—offer page-mode operation. CMOS DRAM goes further with static logic to produce enhanced page mode or Intel's ripple mode. Static-column mode refers to an asynchronous column addressing mode in which the column-address-strobe clock is not required to read multiple locations in the same page after a single row-address-strobe access.

NMB produces both enhanced page mode and static-column mode 256K-by-1 DRAM with CMOS technology. As far as we are concerned, static-column mode parts are not "more expensive and harder to find than ordinary DRAM chips," at least not at NMB.

Tom Goodman
Manager, applications engineering
NMB Semiconductor Corporation
Santa Clara, CA

Thank you for elaborating on the differences between page mode and static-column mode. In our attempt to make the topic of DRAM access modes less confusing, we managed to muddy the waters a bit by lumping these two distinct modes into the same category. However, in both cases the net result is the same. By not needing to vary both the row address and column address, faster access times are achieved.

We are glad to see that NMB supplies high-speed DRAMs. Unfortunately, it may be a while before the price and availability of high-speed parts like these make them attractive for use in industry-standard PCs.

—Ted Forgeron

PS/2 LIST OFF

I am sure you will get a number of responses about the prices you quoted in the article "PS/2 Turns 1" (Douglas Tallman, April 1988, p. 48). I refer to your quoted list price in table 1 (p. 50) for an IBM PS/2 Model 80-041 with 2MB of RAM, two serial ports, and a color monitor. According to my copy of the IBM price list, the Model 80-041 system price is $8,465 ($6,995 for the base model, $595 for the second megabyte of memory, $680 for the 8513 monitor, and $195 for the dual asynchronous controller). In comparison, the Model 80-071 with a 70MB hard disk is $1,500 more for the base, but the second megabyte of memory is included, thus giving $9,270—five dollars less than the price you gave for the lower capacity Model 80-041.

Beyond what I suspect was either a typographical error or the wrong model number, quoting *list* prices is a fundamentally flawed practice—the actual street price is almost never that high, and sometimes dramatically so. For example, I checked with a number of authorized dealers here in the Los Angeles area (none were grey-market operations) for prices on the 16-MHz 386 machines you listed. The prices quoted to me were 20 to 30 percent less than the list price you gave. Clearly, using *fictitious* list prices is highly misleading and grossly misstates the cost of an IBM PS/2. In my small sampling of dealers, IBM's pricing is certainly competitive—in fact, for the configurations you listed, the Model 80-041 is the lowest of all the 16-MHz 386 systems compared. In the future, you might consider printing a small sample of actual prices, rather than using numbers that bear absolutely no resemblance to reality.

Robert L. Milton
Executive vice president
Product development
E.R.M.Associates
Agoura Hills, CA

The list price given for the Model 80-041 was incorrect. According to the official IBM price list for PS/2 models (which has remained unchanged since their introduction on April 2, 1987), the price for the system as configured is $8,585. Unfortunately, the incorrect price slipped through the production process undetected. List prices remain, however, the most equitable means of comparing costs for similar products from different manufacturers. Far from being fictitious, list prices are supplied by the manufacturers themselves. As Mr. Milton points out, street prices can vary a great deal, and not every reader can obtain the same price for the same machine. Using the list price as a starting point, readers can derive the actual price they would pay based on their particular purchasing arrangements.

—DWM

THE OREGON TRIAL

We feel that Jim Roberts' characterization of Oregon Software's Pascal-2 as a disappointment ("Measuring Numerical Accuracy," January 1988, p. 142) cannot be based on the criteria that he used

in that article. The author's characterization was based on two observations: first, Pascal-2's accuracy does not rank among the top performers, and second, Pascal-2's execution time is similar to one-pass compilers. These observations are the result of incorrect use of the Pascal-2 compiler and inconsistencies in the benchmark source program.

Pascal-2 is a compiler that gives the programmer many options. These include optional runtime checks on array index references, 32-bit or 16-bit integers, an optional source-oriented postmortem error traceback and many others.

Our standard installation procedure causes the Pascal-2 compiler to default to 32-bit integers with full error-checking enabled. By doing so, the programmer gets as much assistance as possible from the compiler when developing code. Of course, once the program is debugged and working, the programmer will likely choose to recompile it without any checking whatsoever, to minimize object code size and maximize performance. The programmer may turn off these optional checks and specify 16-bit rather than 32-bit integers, either with compile-time switches or with DOS environment variables.

Other MS-DOS compilers, if they provide any runtime checking at all, tend to make the fastest, shortest, nonchecking options the defaults. C compilers, in particular, rarely provide checking as many obvious errors are perfectly legal in the C language. This is great for benchmark tests, but is it really best for the majority of users?

In examining the various versions of the ACCURACY program that we had downloaded from PCTECHline, we noticed two inconsistencies. First, the constant ITERTRIG has a value of 5 for Turbo Pascal and C, but a value of 10 for Oregon Software's Pascal-2. As a result, the program compiled with Pascal-2 executed twice as many trigonometric iterations.

Second, the program did not make use of Pascal-2's tangent function. Although standard Pascal does not require the implementor to supply a tangent function, we do include one in our compiler. The Pascal version of the ACCURACY program computes the tangent with the expression "sin/cos," increasing execution time and reducing precision (our built-in tangent function returns 80 bits of precision, while your formula uses an intermediate result truncated to 64 bits.)

A fair comparison would be to use sin/cos in all versions of the program, or to use the built-in tan function for all products that supply it—including Pascal-2. Your approach in this article penalizes us even though we provide a tangent.

When Pascal-2's runtime environment and source code are put on an equivalent basis with the other compilers, you will find that Pascal-2 is very competitive with the major optimizing C compilers, both in accuracy and execution time. We would appreciate Mr. Roberts's confirmation of these claims and publication of corrected results.

We realize that establishing a completely accurate benchmark is very difficult to do properly, and we appreciate the fact that Mr. Roberts has made a real effort to gather meaningful results. After all, many PC programmers believe that a 10-line sieve benchmark reveals all that one needs to know about compiler performance.

Don Baccus
Principal engineer
Oregon Software
Portland, OR

There was a typographical error in the published source code for the Pascal version of the ACCURACY program: for Oregon Pascal-2, the number of iterations for the trigonometric tests was incorrectly listed as 10 instead of 5. However, the correct value was used in the program compiled for the actual tests, so the published results are consistent for all compilers.

I apologize for missing the fact that Pascal-2 defaults to long (32-bit) integers; this indeed makes it run slower than with 16-bit integers (the default for all the other compilers tested). Rerunning the benchmarks with short integers reduces the compilation time from 88 to 68 seconds, and the execution time (for 20 iterations with no output) from 37.5 seconds to 24.2. These values compare favorably with the better C compilers.

Pascal-2's FORTRAN-like math library does provide support for complex numbers and, more significant to these tests, a tangent function. Even though I was aware of the library, I chose not to use it, partly to avoid maintaining too many versions of the source, and partly in an attempt to stay with standard Pascal. Upon subsequent reflection, I decided that this decision prevented a fair determination of the best accuracy and execution speed of which each compiler is capable.

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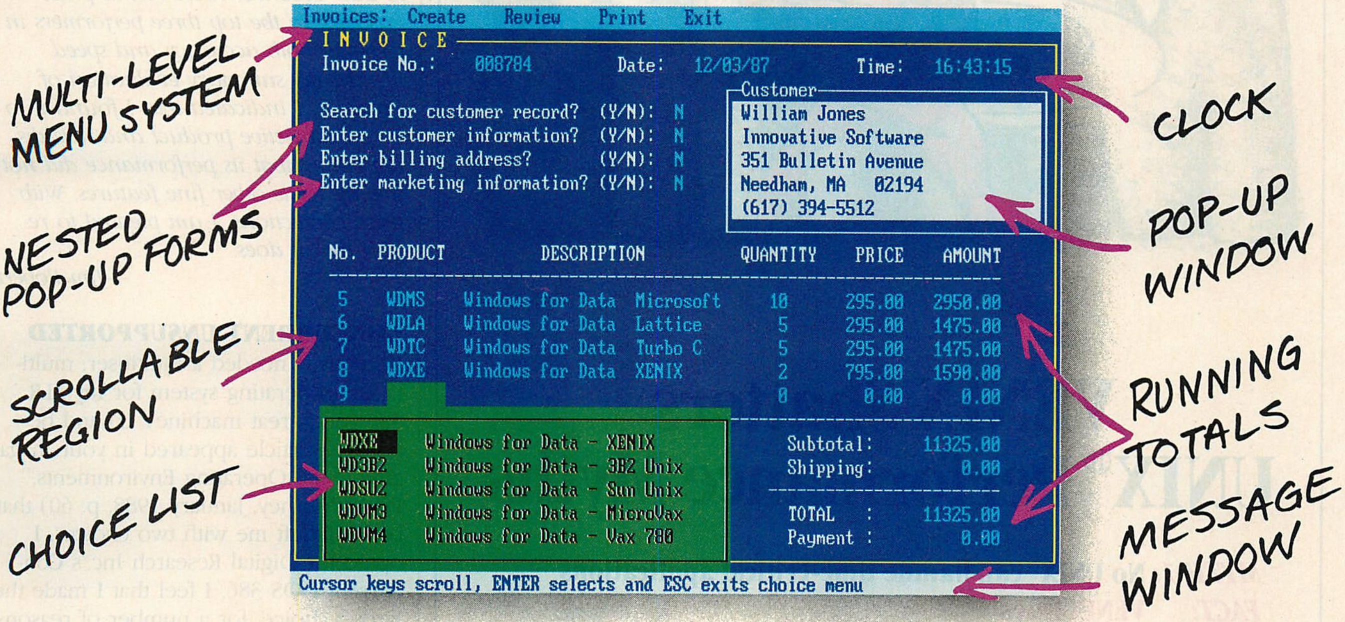

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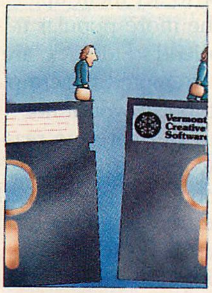

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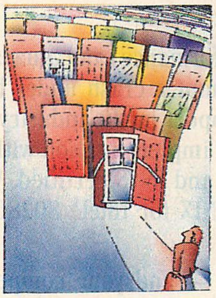

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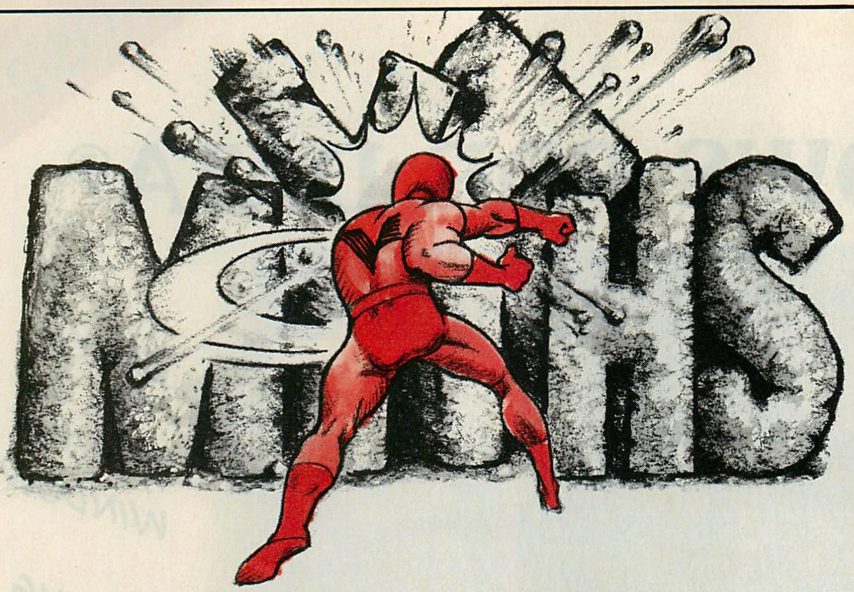

Indeed, with the math library, Pascal-2's error rating improves from 0.83 to 0.80. The compilation time increases by a mere 6 percent (to 72 seconds), but the execution time improves to 22.7 seconds. These results place Pascal-2 in the top three performers in terms of both accuracy and speed.

In my summary evaluation of Pascal-2, I indicated that I found it to be an attractive product and was disappointed that its performance did not live up to its other fine features. With these corrections, I am pleased to report that it does.

—Jim Roberts

CONCURRENT UNSUPPORTED

Recently, I needed a multiuser, multitasking operating system for my ALR 386 (one great machine). Lo and behold, an article appeared in your magazine ("386 Operating Environments," Ed McNierney, January 1988, p. 60) that basically left me with two choices. I opted for Digital Research Inc.'s Concurrent DOS 386. I feel that I made the wrong choice, for a number of reasons. Here are some of them:

1. Concurrent DOS 386 does not support graphics or color on remote terminals. The terminals must also be able to emulate a PC. In no area of the documentation does it spell out the hardware requirements, nor do the sales people deem it necessary to give out this information even when directly queried.
2. The documentation for Concurrent DOS 386 states that certain files (STARTUPX.BAT, for example) are copied to the hard disk during installation. This is incorrect.
3. Although DRI's documentation includes an insert on using 35 popular DOS application packages, it does not explain how to set them up. Even some of the more popular titles, such as Borland's SideKick, are not included. I attempted to set up SideKick myself, but it would not function. Calls to DRI gave me reassurance that it would work, but none of the support people I talked to could tell me how to go about it.
4. According to the sales literature, RealWorld Corporation's RealWorld Accounting modules have been successfully executed on Concurrent DOS. I have yet to find a way. Calls to DRI assured me that RealWorld had tested their product under Concurrent DOS 386. A call to RealWorld rapidly disputed this statement. However, a later discussion

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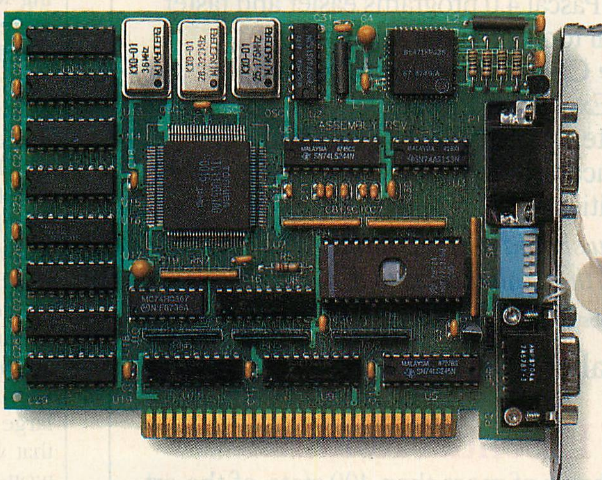

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revealed that DRI had contracted an outside firm to check on compatibility problems.

In my opinion, DRI does not support its product in a professional manner. At the present time, Concurrent DOS 386 has serious deficiencies in both the documentation and the quality of product support provided. Given my experience with DRI, I believe I purchased the wrong product.

Rick Boswell
Boulder Creek, CA

Point 1 amplifies what was stated in the article on page 62: "Remote terminals cannot be transparent to user applications that run on them: applications must be aware that they are running on terminals and use appropriate ANSI (or terminal-specific) cursor positioning and text-output commands."

As indicated in point 2, certain files are not copied to the hard disk during installation of Concurrent DOS 386, which is in contrast to what is stated in the documentation.

With respect to point 3, it is necessary to load the CDOS command interpreter in order to use SideKick with Concurrent DOS 386. This information is contained in the READ.ME file that accompanies the product, rather than in the guide to running applications.

Regarding point 4, Digital Research indicates it is currently working with RealWorld to ensure that the RealWorld Accounting modules will execute on Concurrent DOS 386.

—JS

TAKING AIM AT C

I would like to thank Will Fastie for his straight-shooting editorial, "The Trouble with C" (New Directions, February 1988, p. 27), which took the revolutionary stance that C might not be the greatest thing since hot soup after all. I'm not about to get into a spitting contest over which is the best language; I can think of dozens of more entertaining ways to waste time. My point is merely that there are a number of equally good ways to get the job done, and they don't all have to start with C. As your survey showed, BASIC also gets the job done—so does C, COBOL, FORTRAN, and dBASE.

Like many others, I was shamed into learning C, only to discover that many clients prefer that I continue to use BASIC. They prefer it for one simple reason—it's a lot easier for them to maintain. Now, I have nothing at all against C—some of my best friends are C programmers. But let's get real. A large body of code is already out there that works. Who cares whether it is written in the language-of-the-week or not? Certainly not the users. Anyone paying for my time as a consultant will agree that "if it ain't broke . . ."

Tom Campbell
Irvine, CA

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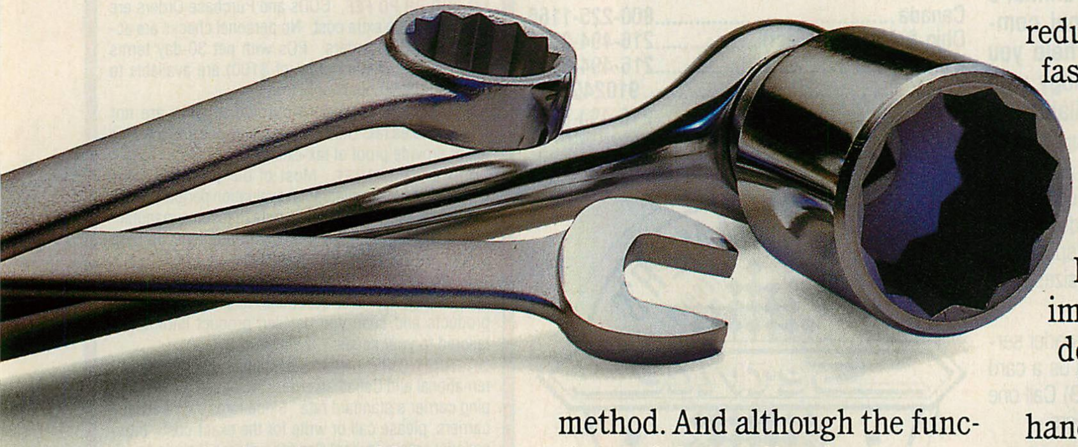


Introducing Emerald Bay. The breakthrough database server technology for developing single and multi-user applications. Emerald Bay provides your programs a common data storage and retrieval method which allows data to be transparently shared across multiple and diverse applications.

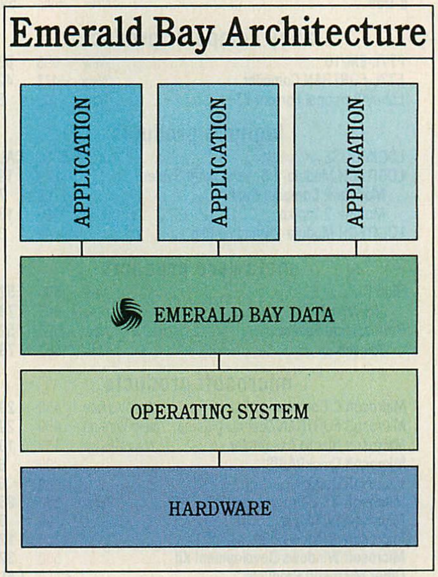
And when you buy one of our tools for "C," dBASE™ or Lotus® developers, we'll give you the personal engine—free. No royalties to pay, no licenses to sign.

Developed by Wayne Ratliff, the creator of dBASE, Emerald Bay is much more than just another DBMS product, it's an entirely new way to manage data. It's designed to provide an open platform for developing applications in several languages and environments, while Emerald Bay maintains data security, concurrency and integrity.

How The Engine Works

Before, data couldn't be readily shared between applications. But with Emerald Bay, PC applications each share a common data storage and retrieval method. And although the functions of the applications may vary widely, any one application can share another's data transparently; there is no data conversion or translation necessary.

When a PC is an intelligent workstation on a LAN, the Emerald Bay database server technology controls all data



security and integrity, including transaction logging with rollback. An application simply makes a request, which is sent to the engine. There, only the essential data is sent back to the workstation. The result is vastly reduced network traffic and faster data access times.

How You Work With The Tools

With the tools we provide, you can easily develop Emerald Bay applications immediately in your familiar development environment.

Emerald Bay technology handles the usually code-intensive management of data, so you can concentrate on what you do best—developing applications.

The ***Developers Toolkit for "C"*** includes well-documented, easy to use "C" libraries that give you the power to create advanced applications, without the effort usually associated with designing and coding a database "backend."

Eagle is Emerald Bay's sophisticated dBASE-like programming language. As the logical evolution of database language, Eagle introduces advanced features, routines and language components, including a compiler, network commands, user-defined functions in "C" and Assembly and automatic index maintenance.

Summit is an "add-in" database management system for Lotus 1-2-3, which gives you sophisticated data manipulation and analysis commands. All three of Emerald Bay's development tools come with the Core Components which include Report Writer, Forms Generator,

ll Give You The Engine.

an Import/Export facility and the Database Administrator.

The ***Emerald Bay Database Server*** is the heart of the multi-user Emerald Bay technology. Its client/server architecture is superior to current implementations of LAN/DBMS products, and increases total system throughput, while reducing network traffic and access times.

Finally, while providing a path to other operating systems such as OS/2, Macintosh and UNIX, Emerald Bay is a microcomputer-based technology that optimizes your *current* hardware investment. There's no need to wait for a new operating system or upgrade your PCs. Because Emerald Bay makes powerful database technology available today, running under MSDOS within 640k of RAM.

How To Find Out More

To get more information about Emerald Bay, call The Programmer's Shop toll-free at 1-800-421-8006.

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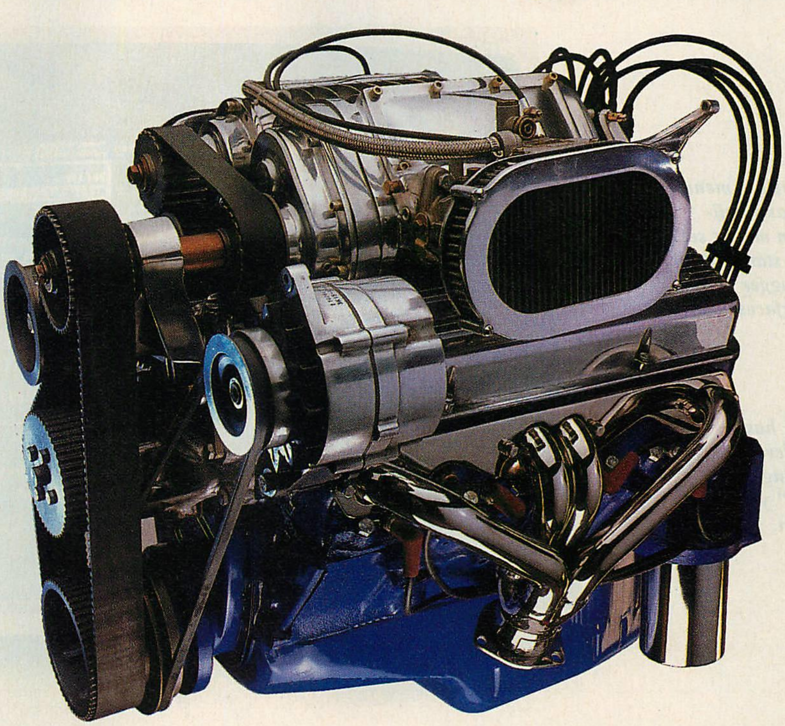


Emerald Bay Engine Specifications

Data Storage

· Max. databases	No limit
· Max. tables per database	1000
· Max. fields per table	800
· Max. field width	512 characters
· Max. records per table	No limit
· Max. width of records	10,000 bytes (no limit on ext. fields)

Index Storage

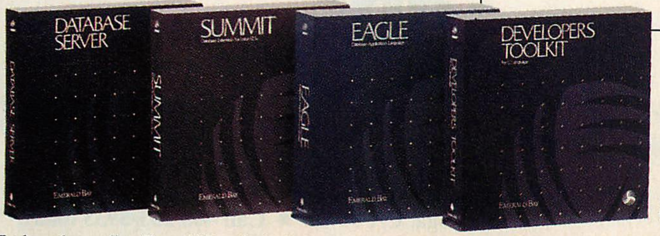
- Composite keys supported
- Mixed data type keys allowed
- Keys of up to 100 bytes in length
- Automatic index maintenance
- Ascending and descending keys
- Case independent keys
- Automatic table indexing on record number

Security And Integrity Features

- Access permissions by Read, Write, Delete, Add and Grant
- All five access permissions work on tables and objects
- Read, Write and Grant access permissions operate at field level
- All data other than binary fields can be encrypted
- Transaction logging, with commit and rollback functions
- Full security functions at field and table level
- Optional data encryption at field level

System Requirements

- MS-DOS 3.1 or greater
- Network database server or Single-user computer: PC XT, AT, PS/2 or 386 compatible, 640K, Hard Disk
- Workstation on LAN: PC, XT, AT, PS/2 or 386 compatible, 640K
- NetBIOS compatible networks supported



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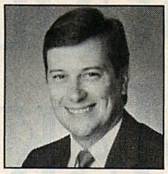

Year of the User Interface

The update to Microsoft's OS/2 toolkit gives the first real look at Presentation Manager. □ Also, the Apple suit and dBASE IV.

If you are an OS/2 developer, your biggest headache so far has been that the Software Development Toolkit has included no support for the Presentation Manager. That has changed; the most current update to Microsoft's OS/2 toolkit finally contains not only the specifications but also, surprise of surprises, some actual code.

To say that the anticipation for the Presentation Manager has been high is to grossly understate the case. Almost every software vendor to whom *PC Tech Journal* speaks says their OS/2 development targets the Presentation Manager; some vendors, such as WordPerfect Corporation, have dropped plans to develop a version for OS/2 1.0 and instead opted for the graphics user interface. That makes this release of the toolkit not only eagerly awaited, but incredibly important. (*PC Tech Journal* previewed the Presentation Manager in its March 1988 cover suite.)

The Presentation Manager included in OS/2 1.1 will likely be essentially the same as described by the specification in the toolkit. That's a real shame, because the user interface is less than expected. To my mind, Microsoft's big customer, IBM, is missing the boat.

That comment deserves some explanation. How do I know that IBM, not Microsoft, is to blame? The truth is I cannot know for sure, and the two vendors are not talking. However, consider the following points: Microsoft has been steeped in the Macintosh environment for some time and is a major supplier of Mac applications; through Windows, Microsoft is a leading advocate of the graphics user interface for the PC; Microsoft expects to leverage its experience into Presentation Manager-based versions of its popular applications. Therefore, Microsoft would hardly design an interface with the flaws present in the Presentation Manager. That influence must have come from IBM.

Part of the problem is no doubt the Systems Application Architecture (SAA), particularly the Common User Access (CUA) portion, which specifies how applications will look no matter which host, PC, or terminal is in use. To be sure, IBM is in a difficult position. It has to protect the investment of its customers who purchase and use terminals as opposed to PCs, and SAA is the means to that end.

This means IBM must design the CUA to fit the lowest common denominator, the terminal. And that, in turn, means decisions about how the graphics user interface looks and works cannot be based solely on the capabilities of the desktop computer.

This approach has two big flaws. First, IBM itself has sold more PCs than terminals by a factor of about five to one, and the gap will only widen. By implication, the desktop computer should get the lion's share of benefit from the SAA design process and not be constrained by the limitations of terminals or past interactive methodologies. Second, if IBM fails to mount an aggressive graphics user environment, Apple will continue its penetration into IBM's native territory, corporate America (that is, if it doesn't impede its own progress with lawsuits—see below).

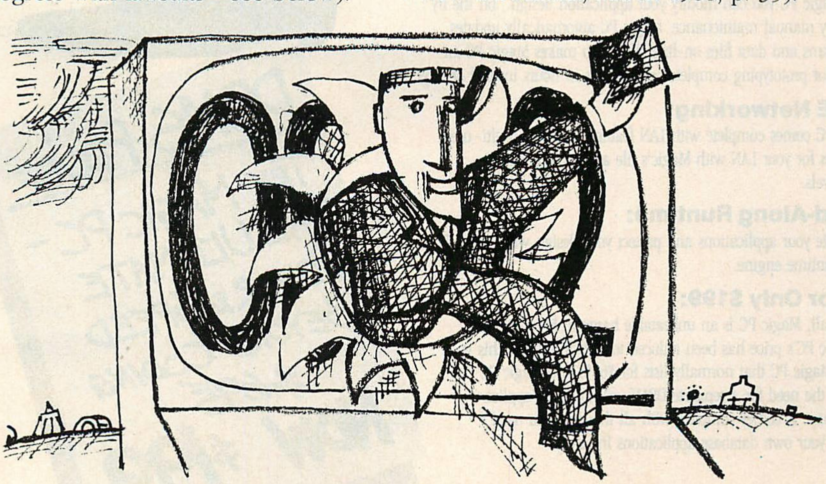

ILLUSTRATION • MACIEK ALBRECHT

A FIRST SCREENING

Notwithstanding its problems, the Presentation Manager's user interface is much improved over Windows. Let's take a first, quick look.

Although the toolkit is not guaranteed to represent the final product, we can assume that OS/2 1.1 will include the following components that make up what the Microsoft documentation refers to as the "User Interface Shell": STARTUP, a TopView-like facility that provides a mechanism to get other programs running (similar to the pull-down menu that appears when the Mac's Apple icon is clicked); Task Manager, a tool that allows switching between applications; File Cabinet, the Windows equivalent of the MS-DOS Executive; and an icon that allows the user to switch quickly to the application in the DOS compatibility box. Serial devices, such as printers, are controlled with the Spool Queue Manager.

STARTUP. Microsoft built a prototype starter program for Windows that was never released. The facility is a much needed one, so STARTUP, which is more sophisticated than the prototype, is a welcome addition; however, it is still a far cry from hDC's delightful ClickStart program for Windows (see New Directions, March 1988, p. 35).

SUDDENLY, MAGIC PC MAKES YOUR DBMS OBSOLETE

Attn Btrieve programmers:

You know how database applications are created — by hacking out line after line of time-consuming code. Most DBMS' and 4GL's give you some programming power. But when it comes to serious applications, they keep you bolted to your seat writing mountains of tedious code. And rewriting it all over again with every design change.

Imagine how much faster you'd be if you could replace the painful coding phase with an innovative visual technology which takes only a fraction of the time: Introducing Magic PC—the revolutionary Visual Database Language from Aker Corporation:

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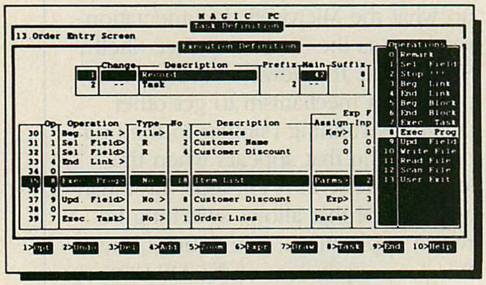

With a powerful set of high-level non-procedural operations you program at only a fraction of the time.

- **Maximum Power AND Simplicity:**

With Magic PC, you can generate robust DBMS applications including screens, windows, menus, reports, forms, import/export, and much more! Plus, Magic PC has one of the friendliest user interfaces you've ever seen. Using Magic PC you can look-up and transfer data through a powerful Zoom Window system. Magic PC even lets you perform command-free queries.

- **Btrieve Performance:**

Magic PC incorporates Btrieve, the high-performance file manager from SoftCraft. This gives you exceptional access speed, extended data dictionary capabilities, and automatic file recovery!

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With Magic PC you can modify your application design "on the fly" without any manual maintenance. Magic PC automatically updates your programs and data files on-line! This also makes Magic PC an ideal tool for prototyping complete applications in hours instead of days.

- **FREE Networking:**

Magic PC comes complete with LAN features. Develop multi-user applications for your LAN with Magic's file and record-locking security levels.

- **Stand-Along Runtime:**

Distribute your applications and protect your design with Magic PC's low cost runtime engine.

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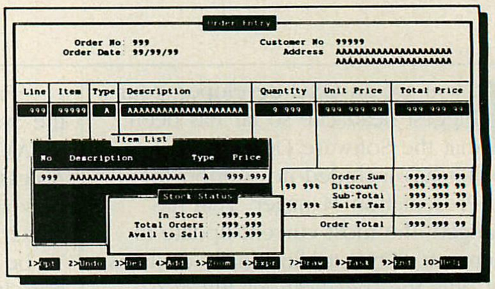
Best of all, Magic PC is an unbeatable bargain. For a limited time, Magic PC's price has been reduced to only $199! Yes, this is the same Magic PC that normally lists for $695! And Magic PC eliminates the need for a separate DBMS, compiler, or application generator. It comes complete with all the tools you need to develop your own database applications instantly.

"Magic PC's data base engine delivers powerful applications in a fraction of the time. . . there is truly no competitive product."
Victor Wright — PC Tech Journal



Pop-up Zoom Windows run multiple programs per screen — with point-and-shoot data transfer between windows!

- **$199 — With A Money-Back Guarantee!**

For a limited time, you can get Magic PC for only $199. And even at this low price, Magic PC is risk-free. If you're not completely satisfied, simply return it within 30 days and we'll buy it back (less $19.95 restocking fee). And if you'd like a preview, Magic PC's Tutorial Demo is available for just $19.95.

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System requirements: IBM PC, XT, AT, PS/2 or 100% compatible with 512K RAM, hard disk and DOS 2.0 or later. 5¼" format, not copy protected. Dealer pricing available. *Return policy valid in US only.

STARTUP comes already configured for the basic components of the Presentation Manager. The user must add other applications and programs. Entries are easily added to a single, nonhierarchical list of programs. If the list is too long, it can be broken into groups; the user can switch between groups to locate the desired program.

Task Manager. When invoked, the Task Manager presents a list of the currently active applications. The user clicks on the desired entry in the list to switch control to that task.

Because it must be accessible to OS/2 applications that are not Presentation Manager-based, the Task Manager cannot rely on the presence of an icon on the work surface (because the work surface may not be there) and therefore cannot use clicking on the icon as a method of activation. Instead, a hotkey combination activates the Task Manager's window. This is a bit strange. Although the Task Manager looks just like an ordinary Presentation Manager application, it does not have an icon, even when the work surface is visible. The rationale is that the Task Manager thus has only one consistent method of invocation. Unfortunately, that method is inconsistent with the way Presentation Manager applications are activated when the work surface is visible (by double-clicking on the icon).

File Cabinet. The File Cabinet and STARTUP are the two pieces of the Presentation Manager that most users will deal with most of the time. The File Cabinet allows the user to perform file management activities, such as starting programs or copying, moving, or deleting files. In Microsoft Windows, each of these activities involves working with a dialog box and, in some cases, entering information via the keyboard. The File Cabinet's major improvement over Windows' MS-DOS Executive is direct manipulation.

Direct manipulation refers to the use of the mouse to point at objects in the File Cabinet window and the ability to perform an action on those objects without being involved in a dialog, especially if that dialog means using the keyboard. The simplest example is copying a file by clicking on that file and dragging it to a new location.

The only direct manipulation allowed in Windows is clicking on a program (or one of its data files) to invoke the program. The Presentation Manager goes further, providing ways to perform most filing functions with the mouse, sometimes in conjunction with the Shift, Ctrl, or Alt keys. Most of the manipulations are easy to understand and use; a few others are mysterious and not entirely intuitive—for example, marking several files to be included in a single operation.

This direct manipulation still does not go far enough. Experimenting with the copy feature, I quickly learned that

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TECH PC JOURNAL Systems Forum '88 SAN FRANCISCO

PC Tech Journal's second annual Systems Forum is just weeks away: June 13–15 at the Westin St. Francis in San Francisco.

The lineup is impressive. The keynote address, "Computing into the 1990s (and how to get there from here)," will be given by Dr. James Nestor, senior manager in charge of microcomputer research and development for Ernst & Whinney. He was a popular speaker at last year's Forum in San Diego. We are also happy to have obtained the services of Steve Ballmer, vice president of systems software for Microsoft, who will deliver the Tuesday luncheon speech, "Why the Graphical Interface?"

Panelists have been recruited from a wide variety of vendor and end-user companies. Vendor participants include Bob Metcalfe, 3Com; Harry Saal, Network General; Bob Epstein, Sybase Inc.; Umang Gupta, Gupta Technologies; Pete Peterson, WordPerfect Corporation; Roy Folk, Ashton-Tate; Scott Tucker, Lotus; Greg Papadopoulos, A.I. Architects; Jim Johnson, Intel PCEO; Gary Stimac, Compaq Computer; and Mike Maples, IBM.

End-user representatives include Danielle Barr, Bank of Boston; Dan Delph, American Airlines; Peter C. Coffee, The Aerospace Corporation; Dennis Quinn, The Phoenix Group; Thomas F. O'Leary, North American Philips; and Cheryl Currid, Coca Cola.

I am really looking forward to this second Systems Forum. For more information, call 800/544-PCTJ. I hope you can join us in San Francisco for what I know will prove a valuable experience.

—*WF*

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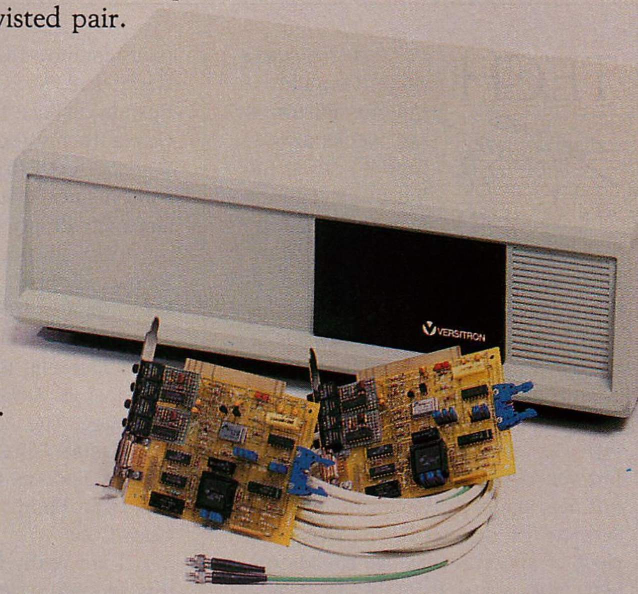

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several types of copying that seemed intuitive did not work. For example, I could not drag a file to a folder (a.k.a. directory) in order to place a copy of the file in the folder. The folder first must be opened in its own window and the file placed in the window. Similarly, I tried to copy a file to another volume (hard disk, diskette, etc.) by dragging a copy of it over the drive icon. Again, a window must be opened on the drive. Most operations in the File Cabinet are similarly restricted.

The simple act of navigating around the hard disk is easier in the Presentation Manager than in Windows. The most helpful addition is the directory tree, which is a diagram of the structure of directories on the disk. Such a facility is available in a variety of DOS programs such as Executive Systems' XTree. The user can choose to see either the full tree, in which every leaf (subdirectory) is visible, or to see an outline tree, in which only the uppermost and selected leaves are visible. With the tree, moving to another directory is just a matter of a few mouse clicks; furthermore, the tree obviates the need to know the name or correct spelling of the desired directory (especially helpful on networks).

The tree shows only folders. Files are listed in a separate window that opens when the folder is double-clicked. The new window displays all the files, including other folders, in a format that is similar to the small icon on the Macintosh; this display shows one file per line, including an icon, the name, the size, and the date. Three types of icons represent folders, executable programs, and everything else (assumed to be documents).

The iconography in the file display window is terrible. The document icon looks like the typical one, with greeked text and a turned-down corner, but it is oriented in landscape mode. This unfortunate choice led me to believe it had some special meaning.

The folder icon is even stranger. Although the tree display quite reasonably uses a tiny picture of a file folder, in the file display window, the icon looks like a little Starship Enterprise or, if you happen to be thinking trees, part of a tree structure. The latter is, of course, the real meaning. This icon choice is a travesty because it gives the system two different icons that have exactly the same meaning, which is anathema to an intuitive, easy-to-use interface. The folder icon should have been used in both cases.

The file display window has no application-specific icons. If icons are supposed to help the user identify the object, then every file type (as determined by file extension) in the system should have definable icons. In such a case, all letters could have the same icon, memos another, programs another; an organization could modify provided icons (or create new ones) to meet its own needs.

One feature of the Presentation Manager that I like very much is *association*. In Windows, it is possible, although more complicated, to associate a file extension with a program so that clicking on the file invokes the program. The user has to edit the WIN.INI file (the AUTOEXEC.BAT of the Windows world) to make such associations. In the Presentation Manager, however, this activity is available as an interactive operation from one of the pull-down menus, so it is much more accessible to the average user.

All my complaints about the User Interface Shell have the same theme: it doesn't go far enough. It doesn't offer enough direct manipulation; it doesn't pay enough attention to details; many items are not intuitive enough. Yet, at the same time, the interface is light-years ahead of Windows and comparable (even better in a few areas, such as the tree display) to the Mac interface.

I hope that Microsoft and IBM will look at the user-interface issues more closely. I also hope that IBM will step out, take some risks, and not be so constrained by its past. The Presentation Manager, the most eagerly awaited of all the OS/2 components, just cannot afford to deliver less functionality or capability than its Apple counterpart if it hopes to gain and hold vital, new, end-user market share.

ROTTEN APPLE

Without question, Apple's legal action claiming that Hewlett-Packard and Microsoft violated a 1985 agreement between Apple and Microsoft about the visual interface of the Macintosh was a stunning surprise to just about everyone, including Microsoft Chairman Bill Gates. It also has software developers worried. As Jimmy Durante used to say, "What a revoltin' development."

While I respect Apple's right to protect its inventions (I thought Apple's action against Franklin's Apple II clone, for example, was justified), I have two major problems with this recent maneuver. First, credit for the visual style

of Macintosh should probably rest with Xerox, where most of the pioneering work was done.

Second, Apple's timing couldn't be worse. The Macintosh is just starting to catch fire in corporate America, and it will be most of another year before the IBM side of the country has anything comparable (that is, both the operating systems *and* the applications to go with them). This is exactly the moment when Apple should be expressing confidence with the message that its systems are superior, and it should be working like crazy to fill the connectivity gaps in its strategy, so it could simply say, "Let the competition roll and may the best desktop win."

Instead, the lawsuit indicates that Apple is nervous about IBM's entree into its territory and the possibility of lost market share and is seeking help outside the marketplace (that is, the courts) to cut its losses. This is bound to cast a negative pall over Apple and will leave the company with a major public relations headache, no matter what the outcome.

Too bad. I thought Apple was getting over its arrogance and settling down to serious business. Looks like I was wrong.

ASHTON-TATE REPOSITIONS

Ashton-Tate has had its share of criticism for failing to respond to increased competition for its flagship product, dBASE III PLUS. That competition has been particularly severe where networking is concerned. Specifically, Nantucket's Clipper and other compilers have offered more features and enabled easier (and less costly) application distribution; Borland's Paradox has led the way with greater ease of use and dynamic query optimization; products such as ORACLE (Oracle Corporation), Ingres (Relational Technology), and Informix (Informix Software) have migrated downward from minicomputers and mainframes, bringing with them application portability and Structured Query Language (SQL) capability. SQL is the favored buzzword right now and dBASE does not have it.

Ashton-Tate is suddenly on the comeback trail. It scored a major coup by netting the marketing rights to the Sybase SQL Server for PC networks. Although Ashton-Tate did not actually develop the technology, the announcement focused much-needed attention on the company with a product that was perfectly contemporary.

The next step is the introduction of dBASE IV. On paper, dBASE IV seems to preserve vital compatibility with dBASE III PLUS, yet addresses all the areas in which that product has fallen behind the competition.

To combat the compiler vendors, dBASE IV purports to offer faster execution speed as well as extended programming features. All the elements that popularized Paradox, including query-by-example, the forms and reports tools, and an application generator, give dBASE IV the appearance of modernity. SQL support makes the outbound connection, meshes nicely with the SQL Server, and gives dBASE IV credibility for serious corporate use.

The one glitch may be that the prerelease publicity concentrates on the end-user features that Paradox brought to light, even though dBASE IV attacks all its competitors in a variety of areas. This publicity strategy may please dBASE devotees, but it also gives Paradox a credibility boost. Unless the dBASE capabilities surpass those of Paradox, Borland executives may end up being the ones jumping for joy.

Will Fastie is the editorial director and founding editor of PC Tech Journal.

Can anyone outperform the dazzling AT&T 6386 WorkGroup System?

Unleash the full power of the 80386 chip.

NO OTHER PC CAN DO MORE FOR YOUR BUSINESS THAN THE AT&T 6386 WORKGROUP SYSTEM.

Compare the AT&T 6386 WorkGroup System to alternative PCs; you'll find it unleashes the full power of the 80386 chip.

In fact, it's one of the most powerful personal computers on the market today.

Its true 32-bit architecture lets you perform real multi-tasking *and* it supports multiple users with simultaneous data access.

But there's much more to the AT&T 6386 WGS than the powerful features that make it a superior computer today.

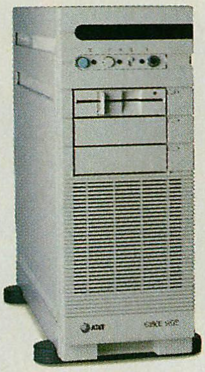
The 6386 WGS is part of a family of AT&T computers that share an open architecture and interface called the AT&T Application Operating Environment.

It's a simple, powerful idea.

The AOE embraces AT&T's approach to industry-standard operating systems, languages, database management, graphics, networking, and more.

Through AOE, AT&T is committed to openness and true connectivity.

So, no matter what exciting new opportunities the software industry provides, the AT&T 6386 WGS is ready for them.



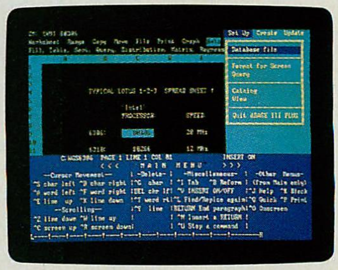
And your investment in AT&T computer equipment will remain safe and sound.

Read on.

To help protect your current software investment we offer a machine that can run in all major operating environments including MS*-DOS, Windows/386, OS/2, UNIX System V, and Simul-Task 386.

Rapid changes in today's software world mean your computer must be ready for anything that comes along.

And it must be able to run all of your existing DOS software: word processing, spreadsheets, databases, forecasting packages, and so on.



The powerful 80386 chip in the AT&T 6386 WorkGroup System works with Windows/386 so you can multitask DOS applications simultaneously – the number of applications is limited only by your expandable RAM capacity.

As OS/2 applications emerge, your 6386 WGS will be ready to run them.

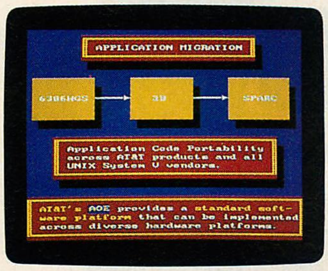
Plus you get the power of UNIX® System V; make the 80386 chip fly as you run powerful multi-tasking UNIX System applications, while Simul-Task 386 lets you concurrently run your DOS applications in their own windows.

And your 6386 WGS can serve up to 32 connected terminals in a multiuser environment.

Take advantage of PC enhancements when opportunities arise.

Running out of expansion slots in your computer is a major headache.

And since the industry promises even more exciting and powerful plug-in boards tomorrow, the problem is just going to get worse.



So, in addition to providing for more memory, the 32-bit path lets you plan ahead now for high-performance boards in the future.

The 6386E WGS has an unprecedented 10 expansion slots: four 32-bit paths, four 16-bit slots, and two 8-bit slots. (8 and 16-bit boards can be used in the 32-bit slots.)

The 6386 WGS offers seven slots: three 32-bit, two 16-bit, and two 8-bit.

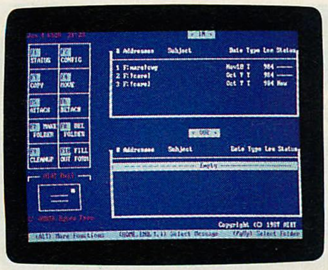
No other 386 computer series gives you more expandability.

Add up to 5 magnetic peripherals inside the machine.

The AT&T 6386 WGS lets you add up to five mass-storage peripherals including tape drive – *right in the machine.* Why clutter up your desk with outboard units?

Keep on using your current media by choosing inboard 3½-inch with a 5¼-inch disk drive option.

Why waste time converting all of your 5¼-inch diskettes just to accommodate a machine that forces you to use 3½-inch diskettes?



Run at up to 20-megahertz clock speed.

The 6386E WGS flies with its 20-megahertz clock speed (16 or 20 megahertz for the 6386 WGS).

Choose from four industry-standard graphics protocols: EGA, CGA, MDA, and AT&T.

The 6386 WGS series supports virtually every graphics display device on the market.

Get total compatibility with existing XT and AT computers.

The AT&T 6386 WorkGroup System is totally hardware-compatible with the IBM** XT and AT.

Virtually all the plug-in boards designed for earlier 8086 and 80286 machines will work in the AT&T 6386 machines.

Expand RAM as needed.

As new operating systems emerge, you need all the RAM you can get.

Today's new operating systems and applications are significantly more memory-hungry.

FEATURE	AT&T 6386 WGS	AT&T 6386E WGS
PROCESSOR	80386	80386
CLOCK SPEED	16/20MHz	20MHz
RAM (STANDARD)	1MB	2MB
5.25" DISKETTE	1.2MB 360KB	1.2MB 360KB
3.5" DISKETTE	1.44MB	1.44MB
TOTAL INTERNAL DEVICES	3 1/2HT +1 FULL	3 1/2HT +2 FULL
TOTAL HARD DISK CAPACITY	435MB	600MB
STREAMING TAPE BACKUP	40, 60 OR 125MB	40, 60 OR 125MB
EXPANSION SLOTS	7	10

More RAM lets you run multi-tasking and multi-user applications much more quickly. You avoid wasting time in unnecessary disk access, because the 6386 WGS lets you expand RAM as your needs increase.

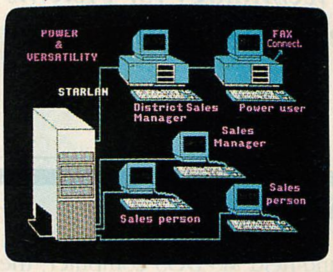
Plan for the future by entering the AT&T Application Operating Environment.

If you're running PC applications today and find that you need to enlarge your workgroup sometime in the future, you won't have to build an applications library from scratch.

The AT&T AOE lets you port your UNIX System V software essentially unchanged to departmental size minis (including AT&T's 3B computer family & RISC based machines) and mainframes, so you can start running powerful 386-based applications now, without fear for tomorrow.

At the same time you can build a fully networked PC workgroup.

The 6386 WGS is compatible with a wide range of peripherals, including AT&T's laser, letter-quality, dot-matrix, and line printers; plotters; and high-performance display terminals.



A single AT&T STARLAN Network can link from 2 to over 100 PCs, which means individuals in your workgroup can share printers, access the same data, and send messages.

AT&T's modular architecture and twisted-pair wiring make it easy for you to add stations as needed.

How to protect your freedom of choice.

To avoid buying the wrong machine, take a close look at the AT&T 6386 WorkGroup System. For more information on the 6386 WGS, the AT&T STARLAN Network, AT&T printers and terminals, and the Applications Operating Environment, call your AT&T Account Executive, Authorized AT&T Reseller, or dial 1 800 247-1212. AT&T can arrange for you to examine the 6386 WorkGroup System, the STARLAN Network, and other components you'll need to build a productive workgroup. Either at a facility near you or by special arrangement at your business location.

From equipment to networking, from computers to communication, AT&T is the right choice.

*MS is a trademark of Microsoft Corporation.
**IBM is a registered trademark of International Business Machines Corporation.
Lotus is a registered trademark of Lotus Development Corporation.

AT&T
The right choice.

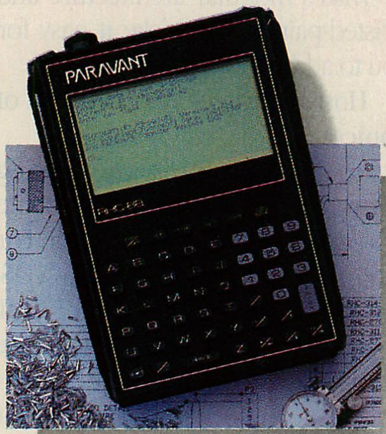
TECH RELEASES

The latest in hardware, software, and technology for systems developers and integrators

Arche Technologies' Arche Rival 386

SYSTEMS

A hand-held MS-DOS computer, the **RHC-88**, has been announced by **Paravant Computer Systems**. Its 16-bit microprocessor is 8088/86 software compatible. The computer's main memory has 512KB of RAM (expandable to 1MB with an optional expansion board). The 4.5-pound RHC-88 is designed to meet military standard



RHC-88 hand-held computer from Paravant

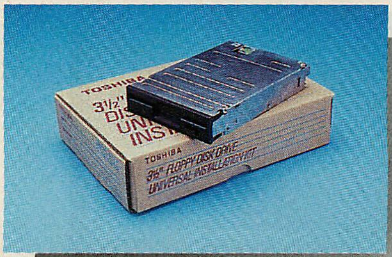
MIL-STD-810D for operation in harsh environments. It features a high-contrast, 5-by-2.75-inch back-lit LCD screen. In text mode, the screen displays 16 lines by 42 characters; in graphics mode, it provides a 256-by-128 pixel resolution. The computer's RS-232 communications port provides a data transfer rate of up to 19.2 Kbps. The unit can be powered by a rechargeable NiCad battery, five alkaline C-cell batteries, or by AC using a transformer. Its color-coded, alphanumeric keyboard includes 52 tactile-feedback keys, which provide 74 characters/functions. $3,995.
Paravant Computer Systems, 7800 Technology Drive, Melbourne, FL 32904; 305/727-3672
CIRCLE 301 ON READER SERVICE CARD

From **Arche Technologies Inc.** comes the **Arche Rival 386**, an 80386-based PC featuring operating speeds of 10 and 20 MHz. It has 2MB of standard memory (expandable to 16MB of 32-bit, zero-wait-state interleaved memory), a 1.2MB 5.25-inch diskette drive, two parallel and two serial ports, eight expansion slots (two 8-bit, four 16-bit, and two 32-bit), and optional 40MB, 65MB, 80MB, and 140MB hard-disk drives, yet it can accommodate up to three, half-height storage devices internally. The Rival 386 cabinet is narrower than most units. The system includes a 14-inch monochrome amber monitor with 1,000-line resolution and flat screen. $4,395.
Arche Technologies Inc., 745 High Street, Westwood, MA 02090; 800/422-4674; 617/461-1111
CIRCLE 302 ON READER SERVICE CARD

PERIPHERALS

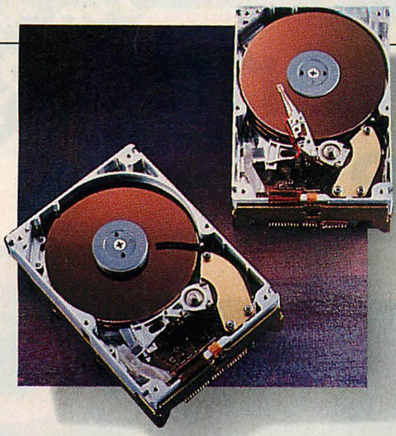
The three-dimensional graphics performance of super graphics workstations is now available on PCs using the **Nth 3D Engine display controller** from **Nth Graphics.** This single plug-in board derives its power from a combination of parallel processing architecture, hierarchical management of the graphics display list, and an object-oriented software interface. The standard Nth 3D Engine transforms 5,000 constant-shaded, 500-pixel polygons per second. Interpolated shading using the Gourand method yields as many as 2,500 100-pixel, four-sided polygons per second. The board supports conic, polygonal, and bicubic structures along with text, any of which can be interactively picked on the screen. The number of light sources is limited only by the size of on-board memory (2MB standard, expandable to 8MB). Primitives can be displayed with anti-aliasing, transparency, and depth cuing applied. Two-dimensional primitive features include scan conversion of lines, polylines, markers, polymarkers, text, circles, arcs, ellipses, and splines. The standard Nth 3D Engine offers 1,024-by-768 pixel resolution and 256 colors from a palette of 4,096. $5,995.
Nth Graphics, 1807-C W. Braker Lane, Austin, TX 78758; 800/624-7552; 512/832-1944
CIRCLE 319 ON READER SERVICE CARD

Toshiba America Inc. has announced that its 2MB (1.44MB formatted) 3.5-inch diskette drive, the **ND356T**, is now shipping with the company's **Universal Installation Kit**. The kit adapts the drive to a 5.25-inch form factor for easy mounting into microcomputers designed for a 5.25-inch diskette drive. The ND356T offers easy transfer of software and data between 3.5-inch and 5.25-inch media. Also available as an option is a software driver that allows the ND356T to be used with DOS 2.0 through 3.1, and the drive to operate in computers that do not have native BIOS support. The ND356T will operate with most standard installation con-



Toshiba's 2MB 3.5-inch diskette drive

trollers. ND356T with the Universal Installation Kit, $219.00; optional software driver, $14.95.
Toshiba America Inc., Information Systems Division, 2001 E. 4th Street, Suite 120, Santa Ana, CA 92705; 714/954-1125
CIRCLE 314 ON READER SERVICE CARD



Quantum's ProDrive Series 3.5-inch hard-disk drive

LANStor disk subsystem from Storage Dimensions

Disk subsystems that fully support NetWare 2.1 are available from **Storage Dimensions**. The subsystems, an expansion of the **LANStor** products line, offer average access times of 17 milliseconds and a high-speed host adapter that has a 1:1 interleave factor to take advantage of the disk's 10-megabit transfer rate. The host adapter eliminates the need for Novell's Disk Coprocessor Board or other hard-disk controllers. The LANStor internal drives offer 148MB and 286MB capacities, and the external models can provide up to 1,144MB in a single, self-contained two- or four-drive enclosure. Several subsystems can be interconnected for higher capacities. Internal subsystems, $3,095 to $5,145; external subsystems, $6,325 to $22,530.
Storage Dimensions, 2145 Hamilton Avenue, San Jose, CA 95125; 408/879-0300
CIRCLE 312 ON READER SERVICE CARD

A family of 3.5-inch hard-disk drives, the **Quantum ProDrive Series**, has been announced by **Quantum Corporation**. The ProDrive Series includes 10 drives with formatted capacities from 42MB to 168MB. The drives feature average access times of 19 milliseconds (ms) or less. Quantum's proprietary DisCache buffer-management system decreases disk transaction times by as much as 50 percent, resulting in seek times of 12 ms in many applications. The ProDrive Series has a specified mean-time-between-failure rate of 50,000 hours. The ProDrive 40S/40AT and 80S/80AT models have capacities of 42MB and 84MB, respectively (the S models have integrated SCSI controllers; the AT models have AT-bus interfaces). OEM prices for quantities of 2,000: 40S/40AT, $520; 80S/80AT, $845.
Quantum Corporation, 1804 McCarthy Blvd., Milpitas, CA 95035; 408/432-1100
CIRCLE 313 ON READER SERVICE CARD

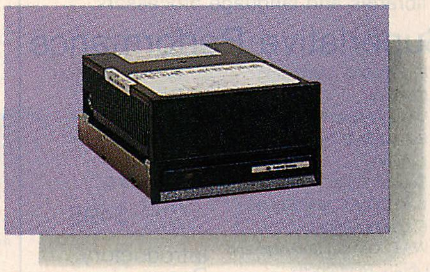
A color PostScript printer, the **QMS ColorScript 100**, has been introduced by **QMS Inc.** Its QMS-designed external controller, based on a 68020 microprocessor operating at 16.67 MHz, comes with 8MB of RAM and 1MB of ROM, enough to handle a full 11-by-17-inch page of PostScript text and graphics. The controller has a built-in

QMS ColorScript 100 printer

20MB hard disk with SCSI interface for permanent downloading of nonresident typefaces or extending temporary font cache memory. For easy connection to IBM, DEC, and Apple environments, the QMS ColorScript 100 has RS-232, Centronics parallel, and RS-422/AppleTalk interfaces. The Mitsubishi G650 thermal-transfer print engine uses a sequential color wax-transfer process to lay down square pixels at a resolution of 300-by-300 dots per inch. Monochrome, three-color, and four-color ink film is available; the printer can generate seven primary colors plus white, and users can simulate an unlimited number of secondary colors. Output is to 8.5-by-11 or 11-by-17-inch thermal transfer paper stock and transparency film. The ColorScript 100 printer has a recommended monthly duty cycle of 4,000 prints. $24,995.
QMS Inc., One Magnum Pass, Mobile, AL 36618; 205/633-4300
CIRCLE 311 ON READER SERVICE CARD

The **BOOT** family of security access products has been announced by **ThumbScan Inc.** With **PCBOOT** for individual PCs or **LANBOOT** for networks, PC owners can prevent unauthorized users from initializing or booting the PC, using software, or accessing files. Both products consist of the **Gordian Access Key** coupled with a half-slot board that plugs into the PC or LAN file server. The Gordian Access Key is a domino-sized, battery-powered device that provides a nonrepeatable password code when held against the terminal screen; the code authenticates the user's right to access the system within seconds. PCBOOT, $179.95; LANBOOT, $379.95; additional Gordian Access Keys, $75.00.
ThumbScan Inc., Two Mid-America Plaza, Suite 800, Oakbrook Terrace, IL 60181; 312/954-2336
CIRCLE 316 ON READER SERVICE CARD

A series of seven **ESDI hard-disk subsystems for NetWare 2.1** has been introduced by **Emerald Systems Inc**. The series, which includes seven disk-drive models, has a data transfer



Emerald System's ESDI hard-disk subsystem for NetWare 2

rate of 10Mbps, an average access time of 16.5 milliseconds, and a 1:1 interleave factor. Available in both internal and external configurations, the basic ESDI hard-disk drives have capacities of 150MB and 300MB; dual-drive models with 600MB combine two 300MB drives using Emerald's proprietary DiskMeld software utility to form one logical

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At a special low introductory price!

WATCOM announces a new team of high-performance C language development systems that deliver proven superior results. Both are available now, at low introductory prices, for IBM PCs, PS/2s, and compatibles.

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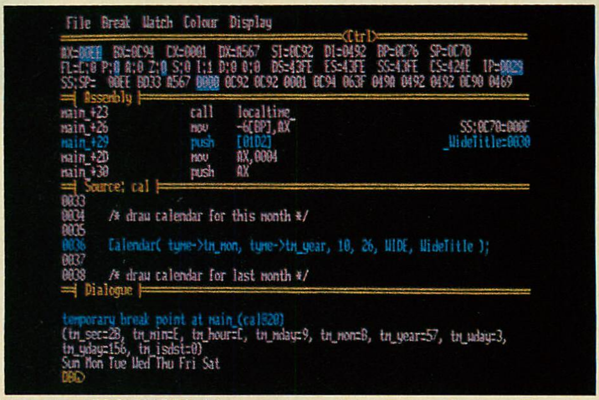
Both systems are optimizers. Express C optimizes your time, WATCOM C6.0 optimizes your code. You win both ways!



With the WATCOM VIDEO debugger you can debug large applications without extended memory.

System Requirements

- System: IBM PC, PC XT, PC AT, PS/2, or true compatible
- Recommended memory: 512K
- Operating system: PC-DOS or MS-DOS, version 2.0 or later.

WATCOM C6.0 Optimizing Compiler and Tools For the Fastest Tightest Code.

This unique development system produces the fastest execution speeds and smallest code available, as shown in benchmark tests against Microsoft C5.0 and Turbo C. It includes the new WATCOM VIDEO Debugger which quickly diagnoses elusive bugs without the need for extended memory even in very large programs. WATCOM C6.0 comes with a copy of Express C and offers a broad spectrum of advantages including: Extensive fine-tuning capabilities. A sophisticated register allocation scheme that eliminates many costly memory references. True register variables. Flow analysis. Altogether it allows your code to run its quickest.

Without a doubt, WATCOM C6.0 is the ideal choice for all memory models, small to huge, and on systems with or without 80x87. Its flexible run-time conventions also allow efficient interfacing with a wide range of libraries and language processors.

Superlative Performance

- ☑ Full ANSI C Optimizing Compiler
- ☑ Visual Interactive Debugger
- ☑ Full ANSI C Run-time Library
- ☑ Source Editor
- ☑ WATCOM C and Express C User's Guides
- ☑ WATCOM C Language and Library References
- ☑ WATCOM Editor User's Guide
- ☑ On-line Help Text
- ☑ Disassembler
- ☑ Overlay Linker
- ☑ Object Librarian
- ☑ MAKE
- ☑ **Express C**

List Price: $495

Introductory Price: **$295***

Software Credentials.

WATCOM C6.0 is the product of 20 years of computer language experience dating back to the creation of WATFOR in 1965. Our commitment to technical support matches our commitment to deliver the world's fastest and most productive programming tools. With more than 400,000 software products in worldwide use and site licensing available for multiple machines and networks, you simply cannot find a better source of software development tools.

The fastest, tightest code
(small memory model*)

	WATCOM C6.0	Microsoft C5.0	Turbo C
25 Iterations Sieve	141 / 11.4	182 / 13.0	154 / 14.1
Dhrystone	992 / 89.0	1246 / 98.0	1144 / 121.0

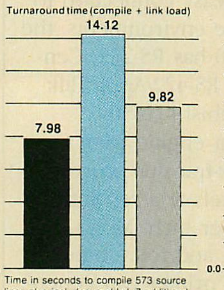
*IBM PC XT

bytes / seconds

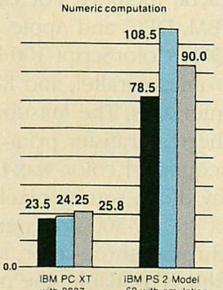
The fastest, tightest code
(medium memory model*)

	WATCOM C6.0	Microsoft C5.0	Turbo C
25 Iterations Sieve	150 / 2.7	184 / 3.0	159 / 3.4
Dhrystone	1001 / 18.0	1232 / 19.0	1156 / 24.0

*IBM PS/2 Model 60



Time in seconds to compile 573 source lines plus includes, and link 7 additional OBJ files created from 1391 source lines IBM PS/2 Model 60, small memory model Program used: GREP



Time in seconds to run 25 iterations of Whetstone
Small memory model (64K code, 64K data)

WATCOM Express C For the Fastest Development Environment.

This seamless development environment offers high speed compilation and the ultimate in programming ease. It is an integrated editor, compiler, debugger, linker and run-time system. With unexcelled diagnostic capabilities, it quickly checks apparently correct code and uncovers common or difficult bugs that other compilers miss. Express C provides you with reliable code and exceptional productivity.

Unparalleled Productivity

- ☑ Full ANSI C Compiler
- ☑ Integrated Source Editor
- ☑ Integrated Debugger
- ☑ Full ANSI C Run-time Library
- ☑ Integrated linker/loader
- ☑ On-line Help Text
- ☑ WATCOM C Library Reference
- ☑ WATCOM Express C User's Guide
- ☑ WATCOM C Language Reference
- ☑ Overlay Linker
- ☑ Object Librarian
- ☑ MAKE

List Price: $125

Introductory Price: **$75***

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Diskette size: ☐ 3½″ ☐ 5¼″
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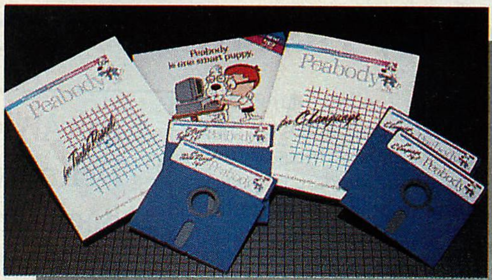
Galaxy/MC tape backup system from Genoa Systems



Peabody for Turbo Pascal 4.0 and C from Copia International

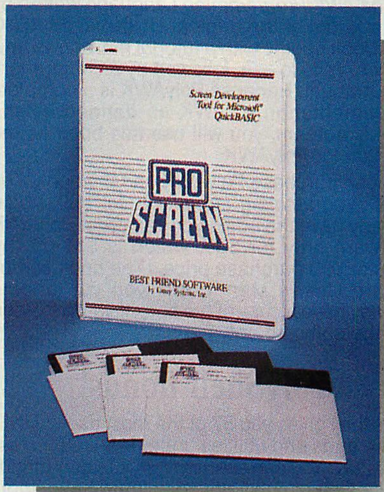
drive. Prices range from $3,995 for the internal LAN150-3122 to $15,995 for the external LAN600-5122.
Emerald Systems Inc., 4757 Morena Blvd., San Diego, CA 92117; 800/553-4030; 619/270-1994
CIRCLE 315 ON READER SERVICE CARD

A line of tape backup systems for IBM's Micro Channel architecture has begun shipping from **Genoa Systems Corporation**. **Galaxy/MC** can be used to transfer files from the PC/XT and PC/AT to PS/2 Models 50, 60, and 80. The systems are also cross-compatible with previous Genoa Galaxy tape systems. They perform image backups at 5MB per minute and can restore individual files from image. Novell network support is provided by Genoa's GenWare network software (which is included with the drives), and optional NetSafe virtual network server software is available to support IBM NETBIOS-compatible networks. The Galaxy/MC is available in 60MB data cassettes and 60MB or 125MB streaming-tape cartridges, in both internal or external configurations. $1,250 to $2,500.
Genoa Systems Corporation, 73 E. Trimble Road, San Jose, CA 95131; 408/432-9090
CIRCLE 317 ON READER SERVICE CARD

SOFTWARE DEVELOPMENT

Pop-up software reference guides for the PC have been announced by **Copia International Ltd.** Currently available is **Peabody for Turbo Pascal 4.0,** which includes 325KB of notes, warnings, and examples for more than 300 reserved words and standard identifiers, and **Peabody for C Language** (Microsoft C Language 5.0). $100 each.
Copia International Ltd., 1964 Richton Drive, Wheaton, IL 60187; 312/665-9830
CIRCLE 324 ON READER SERVICE CARD

Laney Systems Inc. has announced **ProScreen 4**, a screen-development tool for Microsoft QuickBASIC 4.0. Screens are produced in minutes, complete with validation and custom logic. Features include prototyping, pop-up help, mapped keys, robust field tab functions, validation tables and value toggling, message functions, marked fields, five mapped exit keys, full function-key support, custom BASIC code placement before and after field processing, and direct support of all BASIC variable types. Field attributes include color, justification, case, class, order, data type, read/write, validations, and associated BASIC variable names. Screen attributes include message, text, help and cursor colors, field autoskip, field autoerase, key map file, and help specifications. $99.



Laney System's ProScreen 4

Laney Systems Inc., 3 Office Park Drive, Suite 100, Little Rock Arkansas 72211; 501/225-7755
CIRCLE 327 ON READER SERVICE CARD

Microsoft Corporation has introduced five enhanced languages, a programmer's text editor, an enhanced debugger, and other utilities for developing applications with Microsoft OS/2 and IBM OS/2. Designed to allow the development of both MS-DOS real-mode and OS/2 protected-mode applications, the language versions are the **Microsoft C Optimizing Compiler 5.1**, **Microsoft Macro Assembler 5.1**, **Microsoft BASIC Compiler 6.0**, **Microsoft FORTRAN Optimizing Compiler 4.1**, and **Microsoft Pascal Compiler 4.0**. Also announced was the **Microsoft OS/2 Programmer's Toolkit**, which provides documentation and special utilities for developing OS/2 applications.

All of these languages can call OS/2 directly through the application program interface; all share the same math libraries and support very large program development (up to 16MB of real memory and 1GB of virtual memory); and all support interlanguage calling. The CodeView debugger now supports the enhanced languages and can move freely between OS/2 and MS-DOS environments. The fully programmable editor allows as many as eight windows and multiple files to be open at once. The other utilities are **Microsoft ILINK**, an incremental linker for OS/2 only, which links only executable modules that have been changed; **Microsoft IMPLIB**, which creates OS/2 dynamic link libraries; and the **Microsoft BIND Utility,** which creates applications that can run in either DOS 3.x real mode or OS/2 mode (not included with Microsoft BASIC 6.0). C 5.1, $450; BASIC 6.0, $295; Macro Assembler 5.1, $150; FORTRAN 4.1, $450; Pascal, $300; Programmer's Toolkit, $350.
Microsoft Corporation, 16011 N.E. 36th Way, P.O.Box 97017; Redmond, WA 98073-9717; 206/882-8080
CIRCLE 320 ON READER SERVICE CARD

A software utility package for Borland Turbo Pascal 4.0 programmers is offered by **Intermedia Design Systems**

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Bell Labs brought the world UNIX and C, and now professional programmers are discovering AWK. AWK was originally developed for UNIX by Alfred Aho, Richard Weinberger & Brian Kernighan of Bell Labs. Now PolyAWK gives MS-DOS programmers a true implementation of this valuable "new" programming tool. PolyAWK fully conforms to the AWK standard as defined by the original authors in their book, *The AWK Programming Language*.

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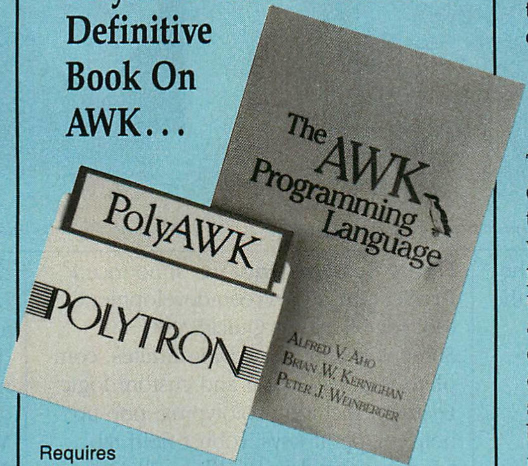
PolyAWK is a powerful pattern matching language for writing short programs to handle common text manipulation and data conversion tasks, multiple input files, dynamic regular expressions, and user-defined functions. A PolyAWK program consists of a sequence of patterns and actions that tell what to look for in the input data and what to do when it's found. PolyAWK searches a set of files for lines matched by any of the patterns. When a matching line is found, the corresponding action is performed. A pattern can select lines by combinations of regular expressions and comparison operations on strings, numbers, fields, variables, and array elements. Actions may perform arbitrary processing on selected lines. The action langauge looks like C, but there are no declarations, and strings and numbers are built-in data types.

Saves You Time & Effort

The most compelling reason to use PolyAWK is that you can literally accomplish in a few lines of code what may take pages in C, Pascal or Assembler. Programmers spend a lot of time writing code to perform simple, mechanical data manipulation – changing the format of data, checking its validity, finding items with some property, adding up numbers and printing reports. It is time consuming to have to write a special-purpose program in a standard language like C or Pascal each time such a task comes up. With PolyAWK, you can handle such tasks with very short programs, often only one or two lines long.

PolyAWK Comes With The Definitive Book On AWK...



Requires MS-DOS 2.0 or above & 256K RAM. **$99**

When you order PolyAWK you receive a copy of *The AWK Programming Language* written by the authors of the original UNIX-based AWK. The book begins with a tutorial that shows how easy AWK is to use, followed by a comprehensive manual. Because PolyAWK is a complete implementation of AWK as defined by the book's authors, you will use this book as the manual for PolyAWK.

You can purchase PolyAWK and the book, *The AWK Programming Language*, for $99. If you already have the book, you can order PolyAWK software only for $85, which is $14 off the regular $99 purchase price. (The book serves as the User's Manual, so you you should already have a copy of the book if you are ordering the software only.)

PolyShell Bonus!

PolyShell gives you 57 of the most useful UNIX commands and utilities under MS-DOS in less than 20K. You can still use MS-DOS commands at any time and exit or restart PolyShell without rebooting. MS-DOS programmers — discover what you have been missing! UNIX programmers — switch to MS-DOS painlessly! PolyShell and PolyAWK are each $99 when ordered separately. Save $50 by ordering the PolyShell + PolyAWK combination package for $149. *Not copy-protected.*

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Prototype With PolyAWK, Translate To Another Language

The brevity of expression and convenience of operations make PolyAWK valuable for prototyping even large-sized programs. You start with a few lines, then refine the program, experimenting with designs by trying alternatives until you get the desired result. Since programs are short, it's easy to get started and easy to start over when experience suggests a different direction. PolyAWK has even been used for software engineering courses because it's possible to experiment with designs much more readily than with larger languages. It's straightforward to translate a PolyAWK program into another language once the design is right.

Very Concise Code

Where program development time is more important than run time, AWK is hard to beat. These AWK characteristics let you write short and concise programs:

- The implicit input loop and the pattern-action paradigm simplify and often entirely eliminate control flow.
- Field splitting parses the most common forms of input, while numbers and strings and the coercions between them handle the most common data types.
- Associate arrays use ordinary strings as the index in the array and offer an easy way to implement a single-key database.
- Regular expressions are a uniform notation for describing patterns of test.
- Default initialization and the absence of declarations shorten programs.

Large Model Implementation

PolyAWK is a large model implementation and can use all of available memory to run big programs or read files greater than 64K.

Math Support

PolyAWK also includes extensive support for math functions such as strings, integers, floating point numbers and transcendental functions (sin, log, etc.) for scientific applications. Conversion between these types is automatic and always optimized for speed without compromising accuracy.

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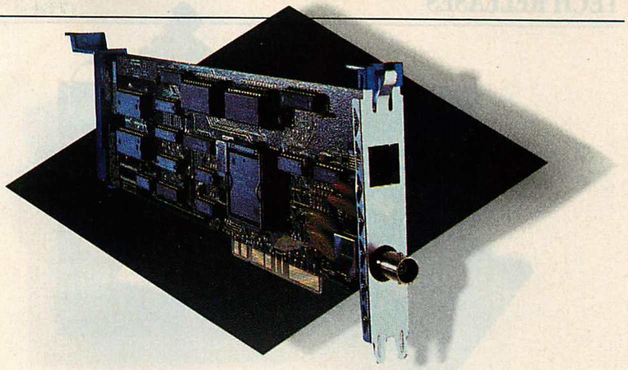
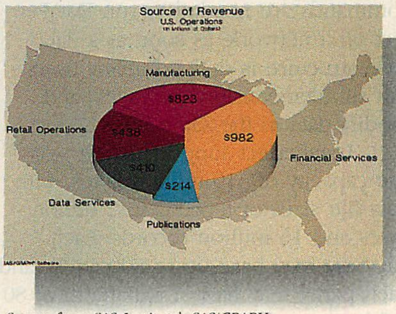
Advanced Digital Corporation's 286 Network Manager



Attachmate's Advanced 3270 Adapter/2

Inc. The **T4 Utilities Library** comprises 19 compiled units of royalty-free useful code. Features include packed Boolean arrays, numeric conversions, procedural and functional parameters, ExtCrt for string editing and keyboard handling, extended DOS, extended text I/O, and fast line-based random access on text files. $34.95.
Intermedia Design Systems Inc., 15 Century Hill Drive, Suite 100, Latham, NY 12110; 518/783-1661
CIRCLE 328 ON READER SERVICE CARD

An expanded version of the SAS System for microcomputers is being shipped by **SAS Institute Inc.** Enhanced products include **SAS/GRAPH**, an information and presentation graphics tool; **SAS/FSP**, a complete information-processing system with full-screen data entry, editing, querying, and letter-writing tools; and **SAS/AF**, an interactive applications development facility for building front-end



Screen from SAS Institute's SAS/GRAPH

menus, computer-based training, and on-line help systems. The new release also features updated and expanded data-management tools, including extended macro capabilities, and enhanced **SAS/STAT** and **SAS/IML** statistical packages. First-year license for base SAS software, $495 for one workstation to $8,495 for 500 workstations.
SAS Institute Inc., SAS Circle, P.O. Box 8000, Cary, NC 27512-8000; 919/467-8000
CIRCLE 330 ON READER SERVICE CARD

CONNECTIONS

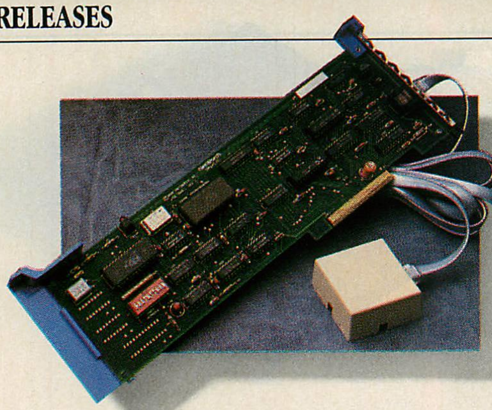
Advanced Digital Corporation (ADC) has introduced the multiuser **286 Network Manager** based on the 16-bit, 10-MHz 80286 and including the Phoenix BIOS for full IBM compatibility. The 286 Network Manager supports 1.5MB of RAM standard on the motherboard and includes a 40MB hard disk, a 1.2MB 5.25-inch diskette drive, and a controller that supports an extra diskette drive and two hard disks. A four-user configuration running under Novell ELS NetWare includes four ADC Personal Network Stations, which use standard IBM-compatible keyboards and monochrome monitors. Each personal workstation has its own 8-MHz 80188, 512KB of dynamic memory, and monochrome video adapter interface. Basic multiuser system, $4,450.

Also from ADC is the **TransFormer 2**, which allows PS/2 systems to be used as file servers for ADC Personal Workstations, running under Novell NetWare or Network-OS. As many as nine Personal Network Station boards may be installed in ADC's **PC-EXBUS**, a PC expansion chassis, with the remaining tenth slot used for an **ADC XI** expansion bus interface board. ADC's TransFormer 2 package, complete with the TransFormer 2 expansion board, PC-EXBUS, ADC XI board, and 3-foot cable, $1,695.
Advanced Digital Corporation, 5432 Production Drive, Huntington Beach, CA 92649; 714/891-4004
CIRCLE 310 ON READER SERVICE CARD

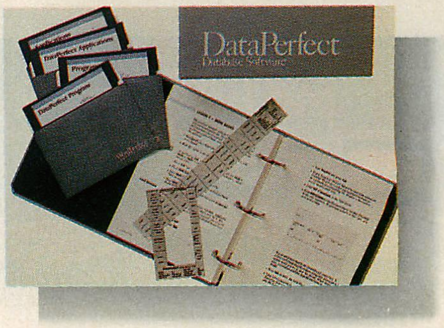
A 3270 micro-mainframe adapter for the IBM PS/2 Micro Channel that will accommodate standard 3270 coaxial cable or twisted-pair wiring has been announced by **Attachmate Corporation**. The **Advanced 3270 Adapter/2**, which connects the PS/2 to an IBM-compatible 3X74 control unit, will run Attachmate's EXTRA! connectivity software or any software written for IBM or IRMA coaxial adapters. Two connectors are available for the new adapter: a modular RJ-11 jack provides direct connection for twisted-pair wiring using a standard telephone-style plug, and a dual-purpose connector accommodates either standard 3270 coaxial cable or twisted pair, depending on the mating connector. With either connector, an on-board balun eliminates the need for the separate, outboard matching transformer normally required for twisted-pair wiring. $595.
Attachmate Corporation, 3241 118th SE, Bellevue, WA 98005; 206/644-4010
CIRCLE 309 ON READER SERVICE CARD

Microsoft Corporation and **Hewlett-Packard Company** jointly announced that **Microsoft LAN Manager/X** (LM/X), which brings the functionality of MS OS/2 LAN Manager to the UNIX System V operating environment, will be available in the first quarter of 1989. Initially developed to run on 80386-based systems under Microsoft UNIX System V/386 3.2, LM/X can be ported to servers running other implementations of UNIX. An LM/X-based server will be able to service requests from workstations running any of Microsoft's other networking products and related IBM products.

LM/X will run on a variety of networking hardware, such as Token-Ring, IEEE 802.3 Ethernet, and 5BASE1 StarLAN. The product will be ported to different protocol environments, including PC-LAN, TCP/IP, and ISO. LM/X maintains consistency with LAN Manager's API, giving it interprocess communication mechanisms such as redirected pipes and mail slots. This support can be extended to other communication protocols such as advanced program-to-program communication. The initial version of LM/X will be licensed to OEMs, who may then port it to other



vNET networking system from NetWorth



DataPerfect database program from WordPerfect Corporation

hardware and software environments. Contact the companies directly for price information.

Microsoft Corporation, 16011 N.E. 36th Way, P.O. Box 97017, Redmond, WA 98073-9717; 206/882-8080

CIRCLE 307 ON READER SERVICE CARD

Hewlett-Packard, Colorado Networks Division, 3404 East Harmony Road, Ft. Collins, CO 80525

CIRCLE 308 ON READER SERVICE CARD

A Micro Channel LAN that uses the high-speed PS/2 arbitration bus has been introduced by **NetWorth Inc.** The twisted-pair networking systems **vLAN+** and **vNET** can interface to the PS/2 without preempting the 80286 or 80386 CPU, so that LAN activity does not decrease the processing power of the PS/2. vLAN+ and vNET support as many as 64 and 128 users per file server, respectively. Bridged together, they have the capability of building a network of as many as 1,000 users. vLAN+, $545; vNET, $595.

NetWorth Inc., 8101 Ridgepoint Drive, Suite 107, Irving, TX 75063; 800/544-5255; 214/869-1331

CIRCLE 306 ON READER SERVICE CARD

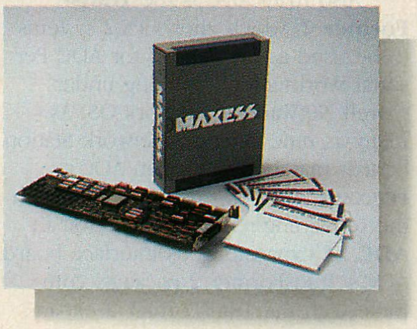
A high-performance program that allows PC users on a NetWare network to share data, print services, and applications with Digital Equipment Corporation (DEC) VAX computers is announced by **Novell Inc. NetWare VMS** allows any VAX VMS computer to function as a network file and print server for IBM PCs with NetWare 2.0a. NetWare VMS is completely compatible with NetWare 2.0a and its applications and with NetWare 2.1. In addition, NetWare VMS can be used to connect to remote VAX systems, and it provides transparent file sharing with the VAX from any PC located on the network. NetWare VMS will be available in the third quarter of 1988. Its price is based per server, from $5,500 to $26,500.

Novell also introduced the **NetWare Archive Server Software**, a dedicated software package that provides on-line archive and restore functions for single or multiple LANs. This software provides each user with the ability to dynamically select directories or files to be archived and restored as needed, and it automatically archives files according to previous user specifications. $1,995.

Novell Inc., 122 E. 1700 S, Provo, UT 84601; 800/453-1267; 801/379-5900

CIRCLE 304 ON READER SERVICE CARD

A LAN gateway that concurrently supports both IBM advanced program-to-program communication (APPC) and 3270 protocols has been introduced by **Communications Solutions Incorporated.** The **Maxess SNA Gateway** supports logical unit (LU) 6.2 and node types 2.0 and 2.1 for both program-to-program and peer-to-peer connectivity. APPC functions provided include parallel sessions, multiple LU support, and both basic and mapped conversation verbs. Its application programming interface (API) is fully compatible with IBM's APPC/PC API. The Maxess SNA Gateway also provides 3270 gateway capabilities, including emulation of a 3274 cluster controller, while the networked workstations emulate 3278/79 terminals and 3287 printers. Other features include 3270 PC-compatible file transfer and an API compatible with IBM's 3271 standard high-level language application programming interface (HLLAPI). Maxess supports as many as 32 concurrent sessions, with each individual workstation able to run multiple sessions. Price for 32 concurrent sessions, $4,995.



Maxess SNA Gateway from Communications Solutions

Communications Solutions Incorporated, 2125 Hamilton Avenue, San Jose, CA 95125; 408/559-1118

CIRCLE 305 ON READER SERVICE CARD

DATABASE MANAGERS

A structured relational database program, **DataPerfect 2.0**, has been announced by **WordPerfect Corporation**. DataPerfect features a menu-driven definition scheme, large data capacity, a powerful formula processor, and compatibility with other WordPerfect Corporation products. No network commands are needed to run DataPerfect on a network; as soon as a database structure is defined, many users can simultaneously view, enter, and modify data in the same file(s).

DataPerfect supports a text storage capacity of 510 million bytes, with data file sizes of more than 2 billion bytes and 16 million records. Each database may have up to 80 panels, and each panel may have a maximum of 80 fields. Formulas may be used to initialize field values, calculate a field value from other data, manipulate dates, and validate fields. Initial copy/file server, $595; five subsequent network stations or five runtime-only licenses, $495.

WordPerfect Corporation, 1555 N. Technology Way, Orem, UT 84057; 801/225-5000

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The material that appears in Tech Releases is based on vendor-supplied information. These products have not been reviewed by the PC Tech Journal *editorial staff.*

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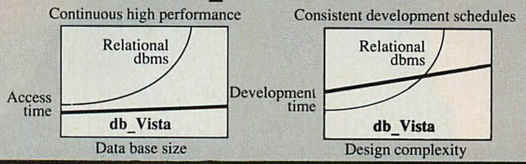

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4 WKS Library for Lotus 123.

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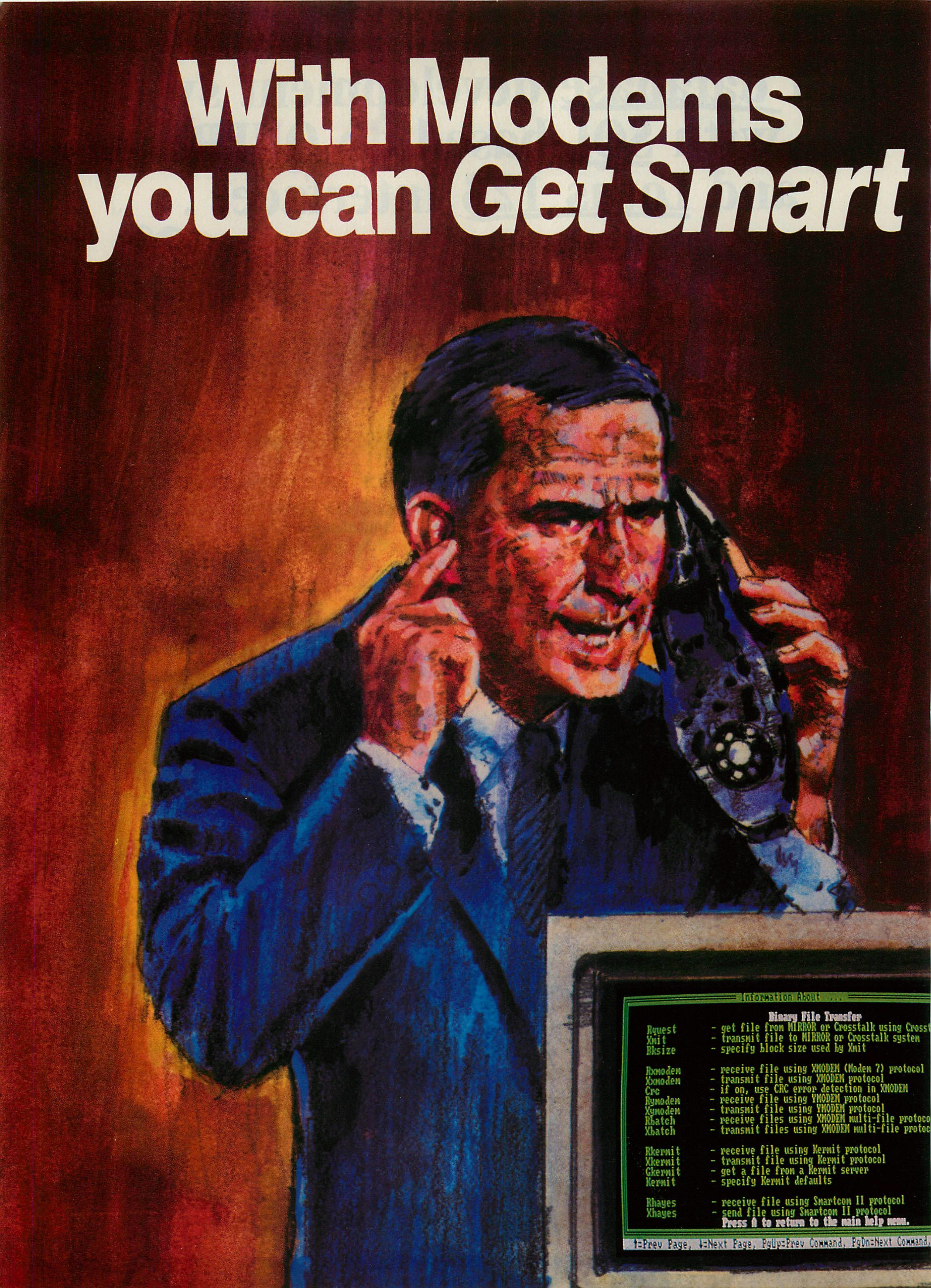
PT 68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Xmit - transmit file to MIRROR or Crosstalk system
Bksize - specify block size used by Xmit
Rxmodem - receive file using XMODEM (Modem 7) protocol
Xxmodem - transmit file using XMODEM protocol
Crc - if on, use CRC error detection in XMODEM
Rymodem - receive file using YMODEM protocol
Xymodem - transmit file using YMODEM protocol
Rbatch - receive files using XMODEM multi-file protoco
Xbatch - transmit files using XMODEM multi-file protoc
Rkermit - receive file using Kermit protocol
Xkermit - transmit file using Kermit protocol
Gkermit - get a file from a Kermit server
Kermit - specify Kermit defaults
Rhayes - receive file using Smartcom II protocol
Xhayes - send file using Smartcom II protocol
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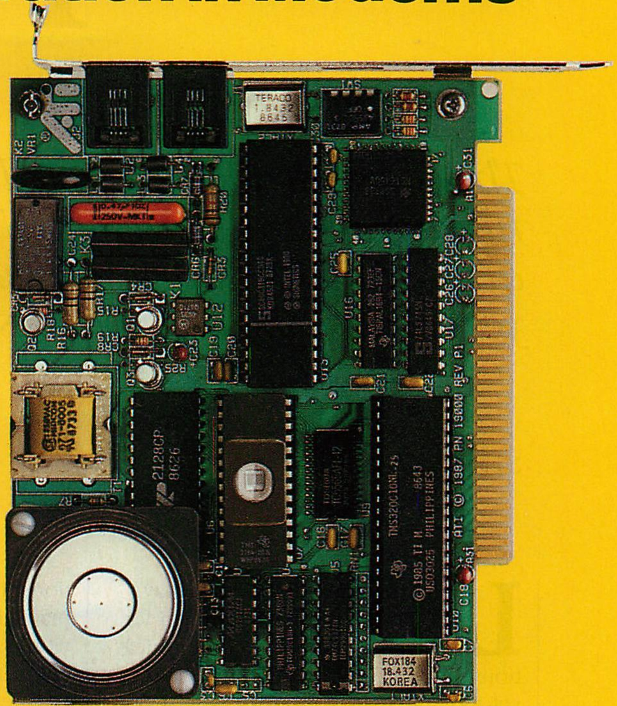

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Network Complexity

The considerations for evaluating LANs are numerous and complex. Understanding the issues and knowing how to judge performance will help you choose the LAN that best fits your needs.

STEVEN S. KING

Local area networks (LANs) may well be the ultimate platform for production software, communications, and sharing computer resources, yet today's PC LAN industry is in a profound state of disarray. Major vendors are standardizing on different technologies; hardware/software incompatibilities persist; and LAN applications are becoming more difficult to integrate.

With this cover suite, *PC Tech Journal* launches a series of in-depth LAN evaluations. Our intent is to apply consistent, comprehensive criteria to distributed technologies that support microcomputers as workstations. LAN performance is assessed using a utility written in C (see the sidebar, "The LAN Performance Challenge," p. 46). The first network evaluated is Novell NetWare 2.1 (p. 58, this issue).

The *PC Tech Journal* LAN series is designed to help developers and integrators who create products for PC LAN platforms, as well as end-user organizations that acquire, develop for, and maintain LANs. Not long ago, this would have been a select group—few companies were willing to invest in the new technology. Today, however, firms feel the urgency of connectivity. Consequently, LANs are proliferating into virtually every sector of the economy.

The focus of this LAN evaluation series is multipurpose office automation networks supporting data management, communications, document production, and group-productivity software. File servers, workstations, and communications hardware are covered from the standpoint of their interaction with the network software.

The LAN industry's priorities naturally correspond to the ascending layers of the Open System Interconnection (OSI) protocol stack. The higher the layer, the more the need for improvement in existing protocols. The internationally acknowledged OSI model, developed by the International Standards Organization (ISO), defines seven layered communications protocols used by PCs, minicomputers, and mainframes to converse across local and wide area networks (see table 1).

The OSI layers are represented in a vertical arrangement, with the lower levels addressing hardware concerns; the middle layers covering internetworking, routing, and flow control; and the upper layers defining protocols for network applications and program-to-program communications.

As the lower communications layers have improved, primary technical concerns have migrated up the protocol stack. Thus, the greatest deficiencies in the PC LAN industry are at the top of the stack, in the session, presentation, and application areas.

The complexity of local area networks evokes the intricate patterns of nature, typified here and on page 59 by examples of sea fan coral.

IMAGE • FOUR BY FIVE PHOTOGRAPHY • JOHN LEI

In the early stages of the LAN industry's development, much attention was directed toward the lower-level hardware concerns, such as topology and media access—major elements of any LAN implementation. But as the technology has matured, media-access methods have been stabilized by the wide acceptance of IEEE's 802 model, which defines specifications for Ethernet, StarLAN, and Token-Ring. Along with the de facto standard ARCnet, the 802-derived topologies increasingly will dominate the network landscape. (For more on LAN topologies, see "LAN Hardware Standards," Art Krumrey and John Kolman, June 1987, p. 54.)

Technical concerns are substantial in the middle, subnet layers, but adequate protocols are available, such as Transmission Control Protocol/Internet Protocol (TCP/IP) and Xerox Network Systems (XNS), both of which perform addressing, routing, and other internetwork functions.

While work goes on defining the upper layers, the PC LAN industry continues to depend heavily on NETBIOS, IBM's program-to-program protocol for PC networks. Despite its wide use, NETBIOS barely qualifies as a true session-level protocol, and it is by no means adequate to support complex multiuser applications on an internetwork. Upper protocol layers should support global name service, authentication, and a rich set of interprocess communications routines. PC LAN vendors tend to tack on these features at the application level instead of including them in the communications subsystem where they belong. In contrast,

THE LAN PERFORMANCE CHALLENGE

Quantifying LAN performance is difficult because of the myriad variables affecting network throughput. Network performance becomes an issue to users only when it noticeably affects application tasks. Most current LAN evaluation techniques have little relevance to the performance of typical DOS LAN applications. Even determining what constitutes acceptable performance is somewhat subjective. Complicating this further are LANs that support diverse applications and users. A network perceived as a good performer for word processing may do poorly with demanding data-management tasks.

Manufacturers of LAN adapters and network test equipment view performance in terms of network media utilization—a network moving 5 megabits per second (Mbps) on 10-Mbps media is 50-percent utilized. This approach reveals much about the efficiency of low-level network components, but says little about application performance.

Network vendors supporting large shared-processor systems often use the speed of a standard software operation to represent performance. This works for easily defined operations performed regularly, but such a situation is not typical for most general-purpose LANs. Application usage patterns are difficult to predict. Other techniques evaluate the data-transfer rate or the delay associated with it.

To correlate network performance with application performance, it helps to look at end-to-end network throughput. For PC LANs, end-to-end throughput can be conceived as the rate of data transfer between a workstation application and the server. If data transfer between network nodes does not significantly impede application performance, then end-to-end throughput is adequate. If data-transfer rates adversely affect application performance, end-to-end throughput is insufficient, and the data-path subcomponents require examination.

Many discrete components lie in the data path between two network nodes, any of which could introduce latency and limit throughput. The path from a client application to the server's disk travels down the client's communications stack, through the network transmission media, up the server communications stack, and arrives at the server's operating system and disk channel. The return trip takes the same route in reverse. A highly layered network might include the following components in the data path: operating system, redirector or shell, router software, data-link software, network card, cable system, caches, and disk channel.

Ideally, LAN performance evaluations should account for end-to-end throughput and the throughput of data-path components. End-to-end throughput is limited by the slowest component. For example, a network without disk caching may be limited by the throughput of its disk channel. If caching is enabled, the disk channel is eliminated as a bottleneck; other possibilities are the workstation's processor speed, media-access software, or network interface card.

High-performance networks such as Token-Ring or Ethernet are not generally thought to restrict throughput, but the advent of 80386 workstations and servers introduces this potential. Token-Ring's maximum throughput is less than 350 KB per second (KB/s) when the overhead of the network card and driver are considered. This is well below maximum 386 throughput and may even limit some fast 80286 machines.

INTRODUCING LANPERF

PC Tech Journal has developed the performance utility, LANPERF, to measure the throughput in KB/s of applications making DOS calls. LANPERF can be downloaded from PCTECHline, *PC Tech Journal*'s online service. It may be run on one or more network stations and synchronizes testing for multiple stations. Portions of LANPERF are written in assembly language to minimize latencies introduced by the test code. Unlike most DOS applications, LANPERF operates continuously, so its throughput approaches the maximum data-transfer rate for DOS operations.

LANPERF can be used to compare the performance of different configurations of a single network or of two different networks. It reveals the effects on throughput made by changing components such as caches, drives, network cards, workstations, server processor, and so on, so that adjustments can be made to improve LAN performance. Some of these components impact throughput substantially, so changing them can yield striking results.

The LANPERF program should run on any network that supports DOS 3.1 or later. Because it uses DOS calls, LANPERF reports throughput statistics for local diskette drives, hard disks, and RAM drives, in addition to network drives. The typical throughput for a 286 machine writing to a fast, local hard disk is approximately 100 KB/s; in this test, the disk channel was the limiting factor. A 16-MHz Compaq Deskpro 386 running LANPERF measured a throughput of 2,067 KB/s when reading from a local RAM drive.

LANPERF performs a read test and a write test, each of which runs for a user-specified number of sec-

minicomputer and workstation vendors have made substantial progress in the implementation of these advanced functions—for example, Sun Microsystems Inc.'s Remote Procedure Call/External Data Representation (RPC/XDR) and Digital Equipment Corporation's (DEC) Session Control.

Ultimately, the quality of services obtained by client applications is governed by the client/server protocol at the top of the stack—the application level. The current industry-standard protocol, Microsoft Network's server message block (SMB), does not support a rich set of client services. Some successful LAN vendors do not rely on SMB and have their own file system interface. Novell's NetWare Core Protocol (NCP) and Sun's Network File System (NFS) are examples of robust client/server protocols that are open to programmers and developers.

ACROSS THE LAN-SCAPE

The diversity of LAN applications and implementation techniques makes it difficult to establish evaluation criteria. New LAN products and even new *classes* of products appear at an amazing rate. Nearly as many variations of LAN technologies have emerged as there are types of installation sites and applications. It seems for every LAN technology, there is a different LAN implementation philosophy.

One striking dichotomy in the LAN industry is the two separate approaches to network resource management: *peer-to-peer* and *centralized*. The peer-to-peer view is typified by high levels of storage and peripheral resources at

onds. The read test creates a temporary file containing random data and reads it repeatedly; the write test writes random data to a temporary file. For both modes, the block size and file size may be set from the command line. To achieve overlayed reads or writes, file size is set equal to block size; otherwise operations will be sequential. The DOS extended open mode for reads and writes may be specified, including deny-read, deny-write, deny-read/write, deny-none, or compatibility mode. These parameters allow LANPERF to simulate standard file operations made by DOS applications. Changing any of them can impact network performance.

Varying block size, for example, has a dramatic impact on application throughput. Blocks sizes of 512 bytes or larger are close to the capacity of a network packet and result in high throughput figures; small blocks (such as 1 byte) are processed individually and require a packet per block. In testing, the throughput for 1,024-byte reads by a 10-MHz AST Premium/286 was 98.13 KB/s. The same configuration tested with 1-byte blocks yielded 3.58 KB/s, revealing the cost of working in small block sizes.

File-open modes affect performance if network software supports local caching in the client station. Local file caching lets applications perform small read and write operations to local cache buffers rather than the server. The contents of local buffers are updated periodically on the server. Local caching will not work for large data transfers because buffer size is typically small. Operations that open files nonexclusively cannot use local caches due to data-synchronization needs on the server.

Because applications do not generate continuous traffic, as LANPERF does, the KB/s metric must be interpreted into application terms. One approach is to measure times for loading network applications into memory and standard application operations, such as searches, sorts, indexing, copying, and so on. Then, using the same configuration, run LANPERF to determine the throughput figures. This reveals the levels of throughput needed to perform application tasks in a specific elapsed time. Application performance for another network configuration can then be predicted by comparing LANPERF throughout results for both networks.

Although LANPERF provides a reliable method of comparing throughput for various configurations, correlating application performance with throughput measurements is not an exact science. No standard profile for application demands exists; consequently, the LAN evaluator has the burden of identifying application usage patterns and interpreting LANPERF throughput measurements.

PERFORMANCE TRANSACTIONS

Although it is a useful measurement, continuous throughput is only one aspect of LAN performance. A data-transfer operation does not reach full throughput levels instantly—a session must first be established between two network nodes. This may involve exchanging session IDs, sockets, or handle numbers, and negotiating transfer parameters. The management of sessions take place on more than one protocol level, with various layers conducting handshaking and initialization sequences.

The DOS request-response architecture introduces significant delay into file operation when combined with the natural latency of the network link. Every DOS request to the file server must wait for a response before the next operation is performed. Opening and closing files also incurs delay.

Many network applications involve more than sustained transfer operation and require smaller operations with high administrative overhead (databases, for example). Such an operation does not achieve throughput equal to the capacity of the session's link. Consequently, the maximum throughput figure as measured by LANPERF is not the only meaningful representation of network performance.

For repeated operations in which administrative overhead is substantial, a *transaction* is a more significant representation. A transaction correlates well to functionally related activities, such as open-read-close, that are bounded by initialization and completion sequences. For performance modeling purposes, many types of transactions could be considered, each with different levels of administrative overhead. A transaction for a message-passing session comprises all operations required to establish the session, transfer data, and terminate the session. A transaction for a database session includes opening, locking, reading, writing, and closing files.

The performance characteristics of transactional operations in network environments require a more sophisticated utility that can introduce delays into operations and model complex application traffic patterns. However, the transactional approach is not a fully developed methodology. The LANPERF utility, as introduced, is designed to measure throughput for sustained file operations involving many iterations. Future enhancements to the program are anticipated.

—*Steven S. King*

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the workstation, thus handing large system administration responsibilities to each user. The centralized view, on the other hand, holds that network resources are best managed and maintained on powerful, centralized file servers. With this approach, workstations need high processing power, but are not the ideal location for mass storage, peripheral, and backup resources.

Biases toward either of these approaches impact design processes for LAN products and network application software. The ironic credo for advocates of centralized resources is, "Distributed doesn't mean decentralized." This translates to: processing power may be distributed to the end users' workstations, but the responsibilities for network administration should be centralized, as they are on minicomputers and mainframe systems. Supporters of the peer-to-peer approach, in contrast, believe that the workstation is the center of the automation universe, both in terms of resources and management responsibilities.

Although any LAN can include elements of both strategies, most vendors fall easily into one camp or the other. LAN vendors such as Banyan Systems, Novell, and 3Com support high levels of centralized management and resources. With systems from these vendors, the network can be administered by any end-user node, but administrative responsibilities typically are held by a select group with special privileges. Hard drives, communications equipment, and tape backup units are generally situated at dedicated servers, not at workstations.

Vendors with a peer-to-peer orientation include TOPS and Apple Computer. Many low-end PC LAN products lack centralized hardware support and management facilities, and consequently fall into the peer-to-peer category by default. Representatives of the low-end or *workgroup* LANs are Network-OS, from CBIS; Port, from Waterloo Microsystems; and 10NET, from 10NET Communications.

Peer-to-peer LANs are not as reliant on heavy communication between nodes, because the stations store much of their data locally. One disadvantage to this approach is that shared data are fragmented onto local drives, making access by many users difficult. In some applications, fragmented data may not be an issue. Peer-to-peer LANs rely on a higher level of effort and systems knowledge on the part of end users who share each other's equipment. This is impractical in many business environments. Centralized resources are probably the better choice in a system where end users are not overtly computer oriented.

TABLE 1: ***Network Protocols***

OSI LAYER	PROTOCOLS	SUPPLIER
Application/ Presentation	NCP (NetWare Core Protocol)	Novell
	NFS (Network File System)	SUN Microsystems
	SMB (Server Message Block)	Microsoft Corp.
Session	APPC (Advanced Program-to-Program Communication)	IBM
	DNA Session Control	DEC
	NETBIOS	IBM
	RPC (Remote Procedure Call)	SUN Microsystems
Transport/ Network	XNS (Xerox Network Systems)	Xerox Corp.
	TCP/IP (Transmission Control Protocol/Internet Protocol)	U.S. Department of Defense
Data link/ Physical	ARCNET	Datapoint
	Ethernet 802.3	IEEE
	Token Bus 802.4	IEEE
	Token Ring 802.5	IEEE
	StarLAN	IEEE
	Others	

The upper protocol layers are not yet standardized and vary among vendors. On the session layer, only NETBIOS is widely used for PC networks. XNS, at the transport layer, has been adopted by Novell and 3Com, among other vendors.

LANs with more centralized resources require higher bandwidth to support regular file I/O and queuing of requests to the servers, and this can mean higher costs for hardware. The payoff is that the centralized resource helps ensure the availability, integrity, and backup of shared data.

STANDARD BEARER

If the two approaches are different in most other aspects, they are affected equally by the atmosphere of evolving standards. LAN standards must advance if the industry is to realize its potential to provide computer users with a uniformly high level of distributed services for the spectrum of applications. Only when standards have become well defined will vendors be able to differentiate themselves by the quality, dependability, performance, and cost of their products. Without standards, products providing the same services are not interchangeable and vendors can lock buyers into sole-source relationships that encourage neither innovation nor rapid progress for the industry.

Standards are often at war with proprietary interests. The struggle for international telecommunications standards involving IBM's System Network Architecture (SNA), OSI, and Integrated Services Digital Network (ISDN) is an example of this. Each of these interests wants standards, but each would prefer standards that closely relate to its own products. Witness the slim likelihood that protocol components from vendors such as DEC and Hewlett-Packard (HP) will be freely interchangeable in the near future—even if they support OSI. In the minicomputer and mainframe industries, standards provide a common language more often for efficient communications between dissimilar systems, rather than open interchange of vendor components.

The PC LAN industry has similar examples, and worse, the standards presently in place are based on older, single-user technologies and address somewhat primitive network functionality. The most advanced network functions are available only in proprietary technologies, and the progress of LAN standards is far from keeping pace with product development. A bigger problem with standardizing these advanced technologies, even now, is that not all vendors will support them. For example, major LAN vendors currently are adopting different electronic mail (E-mail) and database engines, thus making standard development platforms difficult to achieve.

The chances for the LAN industry to standardize rapidly on much-needed distributed file systems, client/server interfaces, store-and-forward capabilities, or session-layer protocols do not look promising. As with the large systems industries, the best that can be hoped for is that proprietary products

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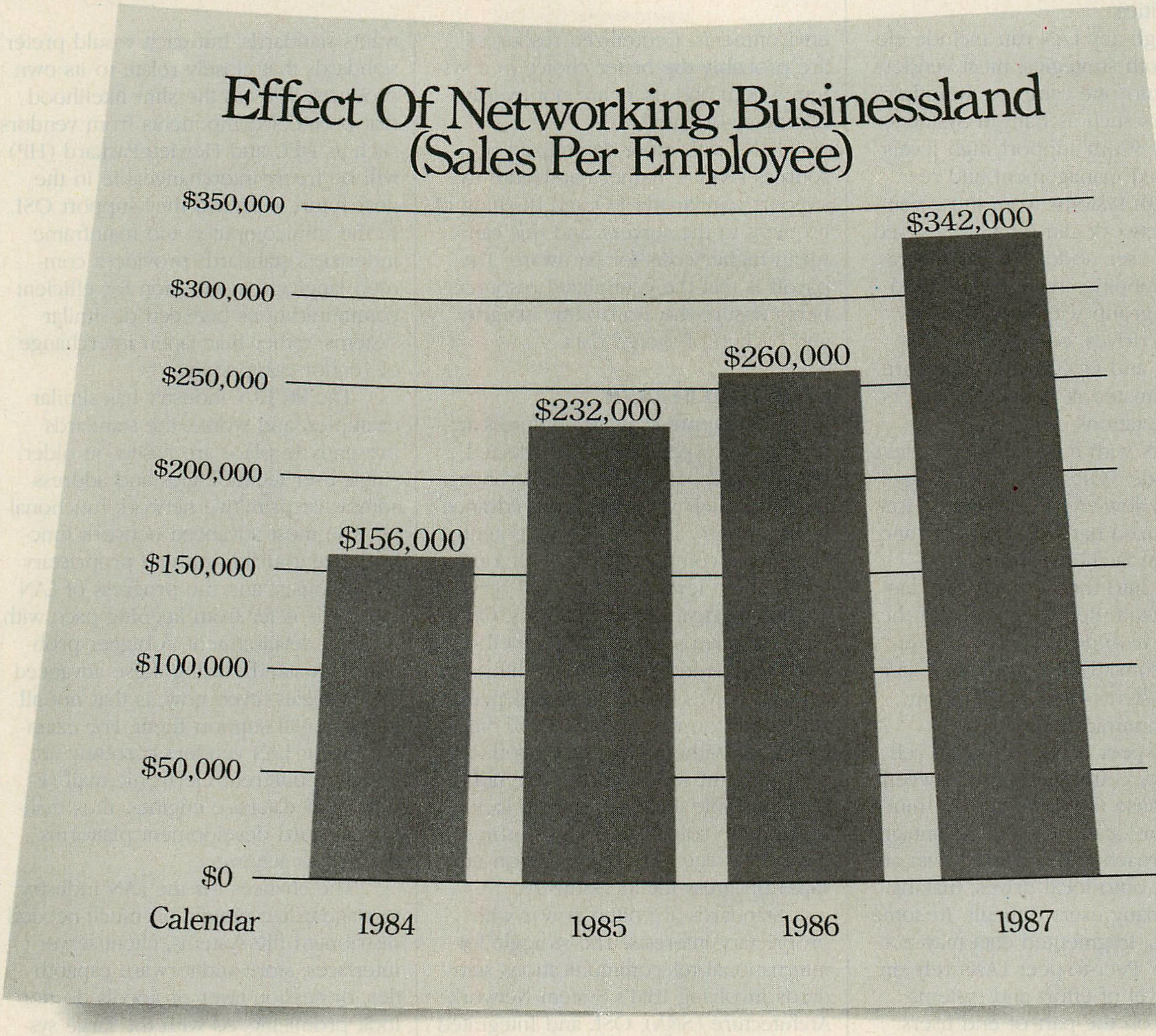

from major vendors will talk to each other in a relatively seamless fashion.

This problem is compounded by the possibility that LAN standards may not evolve in "obvious" directions. Normally, standards are developed by international organizations, or large industrial interests in a particular industry. In some cases, though, when standards have not provided what users require, a smaller company with a superior product may spontaneously create a new standard against all odds—the Hayes Smartmodem, for example, or Adobe's PostScript.

The LAN industry has reached the point where standards such as DOS and NETBIOS have fallen too far behind user needs for advanced network functions. If new products such as OS/2, LAN Manager, and advanced program-to-program communication (APPC) do not fill the gap quickly, products from other sources will.

One possibility is that LAN purchasers may become dissatisfied with the slow development of PC LAN standards and instead buy their LANs from workstation vendors such as Sun or Apollo. These vendors can support DOS applications with DOS coprocessors or software emulation and thus enjoy the benefit of powerful network services not available with PC LAN industry products. In the short term then, LAN products must be evaluated conscientiously and with careful anticipation of the evolving industry.

A GAUGE TO APPLY?

Despite this divergence of LAN philosophies, general-purpose office automation LANs can be evaluated against a common set of criteria. The following considerations were developed from study of the services provided by PC LANs, UNIX workstation systems, and minicomputers and mainframes.

Interoperability. With the virtual explosion of new and different LAN architectures into the market, interoperability is fast becoming a priority for many organizations. Applications on a given LAN must be able to interact with applications on other systems that might include dissimilar LANs, workstations, minicomputers, and mainframes. Often, two or more dissimilar architectures are supported within the same organization—sometimes at the same site.

Part of the interoperability requirement is support for multiple client operating systems. Also important are gateways providing transparent protocol conversion between user application processes running on different systems. TOPS has found an excellent niche providing interoperability between Apple-, DOS-, and UNIX-based clients. Other vendors, such as Banyan, Novell, and 3Com, are directing major efforts to achieve similar functions.

Application programming interfaces. LANs are becoming the platform of choice for PC application developers. A full-featured LAN should support a large number of callable software routines; at a minimum, support of standard DOS 3.x function calls should be provided. Important intersystem APIs include IBM's high-level language application programming interface (HLLAPI), APPC, NETBIOS, and the Berkeley socket interface for TCP/IP.

Despite the divergence of LAN philosophies, general-purpose office automation LANs can be evaluated against common criteria.

The DOS criteria requires that client applications write and read from network disk files in the same way they would with files on local disks. Some of the APIs to be expected from a full-featured LAN include services for file management, usage accounting, remote jobs, printing, asynchronous servers, network diagnostics and management, name servers, database servers, and interprocess communications. Advanced network functions should be evaluated for the degree of programmer accessibility provided by the vendor in the form of link libraries and well-produced documentation.

Communications protocols. LANs depend on their communications protocol stack for much of their performance and functionality. Inefficient code at any protocol layer is a potential bottleneck. At odds with performance is the need for well-structured protocol interfaces between communications functions. Deficiencies in the stack stifle a LAN's ability to grow and to internetwork. Many LANs need to show improvement in this area.

Products based on older technologies tend to leave out layers or combine different communications functions into a single component. Even the high-end LAN vendors are ambivalent at times about highly layered communications software. This is understandable when considering the performance penalties associated with dividing communications processes into discrete modules, each with its own I/O interface. In the long run, however, the benefits of many independent layers outweigh the drawbacks of any performance or development overheads.

Well-defined protocol components allow sections (modules) of the stack to be modified or replaced without affecting the other layers. Also important, a layered approach provides optional points of interface between dissimilar systems. For example, if OSI-type layers are in place, designers can interface systems at the data-link layers with a bridge, at the internetwork layers with a router, or at the application layers with a gateway. Ideally, a LAN vendor should provide more than one type of protocol at each layer of the stack, allowing LANs to adapt to different budgets, communications resources, and application demands.

Network management. Without strong network management capabilities, local and wide area networks prove unreliable, even if they are built with well-designed protocol stacks and mature distributed operating systems. Network management tools should provide the system manager with network monitoring and reconfiguration capabilities from any node. Statistics on network traffic and server access patterns should be available for off-line analysis. Full-featured network management utilities are invaluable for diagnosing network faults, managing connections, leveling loads, and planning capacity.

None of the current PC LAN offerings has fully developed network management facilities, but the minicomputer and mainframe architectures have had more time to develop sophisticated network management. DEC's Digital Network Architecture (DNA) is a fine model for establishing network management criteria. It allows a system manager or an automated management process to monitor and configure components of the protocol stack. DEC supplies a high-level network management command language so that programs can enhance network management functions. These same types of services are also necessary for the expansion of PC LANs.

Security. In many LANs, security is a priority and a constant user concern. Users of stand-alone PCs are accustomed to the physical security of storing their data on a local hard disk in their own offices, which they lock up

when they leave. When a stand-alone user starts using a LAN, this type of security is not apparent.

LANs can provide excellent levels of security, but this involves a host of concerns, including the vulnerability of data on shared hard disks, the possible disclosure of data printed on network printers located in common areas, the dangers of unencrypted passwords on the wire, and the information dissemination provided by LAN-based wide area E-mail systems.

Although all LANs have some security features, many are deficient in this area, particularly those that use DOS to host their server operating functions. Some distributed systems, such as Sun Microsystems' DFS, enhance their authentication and server security with techniques based on the National Bureau of Standards' Data Encryption Standard (DES). Shared resources, such as printers and directories, need more protection than a simple password. A sophisticated LAN security system includes functions such as login tracking, forced password change, file and volume encryption, and audit trails.

Costs. The cost associated with an application on a LAN is generally understood to be less than for the equivalent application on a minicomputer. This widely held belief can be misleading, however. Cost evaluations must take into account the many indirect costs associated with LAN.

For example, the direct hardware and software costs for a fully loaded 80286 workstation connected to a shared file server may be less than $5,000—especially if the file server costs are distributed across many stations. But even if the shared equipment costs are factored into the price of a workstation, the figure remains unrealistically low. The actual "loaded" cost for a 286 workstation, including cabling, maintenance, training, support, physical improvements for central servers, and consulting, can, in some cases, exceed $10,000. This is close to the cost for a minicomputer workstation, with a portion of the CPU expenses factored in.

Cost calculations for LANs are not particularly straightforward or self-evident. The short-term savings of implementing a low-speed topology such as StarLAN, for example, can be wiped out in the long term by losses in productivity associated with low application performance.

Market viability. Many firms from diverse commercial sectors are seriously developing and marketing LANs. These manufacturers can be organized into no fewer than five classes:

1. PC-centric firms, including Banyan, Microsoft, Novell, and 3Com
2. IBM and its many value added resellers
3. "Voice vendors," such as AT&T and Northern Telecom
4. Minicomputer vendors, such as DEC, HP, and Prime
5. Engineering workstation vendors, such as Apollo and Sun.

Minicomputer and workstation vendors are included in LAN considerations because the distinctions between micro- and minicomputer-based systems are diminishing. This process is similar to the way in which the distinctions between voice and data systems are diminishing, as voice vendors go digital and are able to support PCs in addition to telephones.

Current networking solutions from PC LAN vendors are in many ways crippled by the heritage of an older, single-user technology.

Standard features on minicomputer networks are often what PC LAN vendors wish they could offer. Some minicomputer vendors, such as Prime, are offering 386-platform versions of their products that look like high-performance file servers, but bring the advantage of terminal support and facile connections to larger, shared processor systems. Midrange processors from vendors such as DEC and HP increasingly are configured as file servers. These minicomputers can support DOS clients with SMB client/server protocols, and, in the case of the DEC VAX, even Novell's network core services, running as a guest operating system.

Current solutions from PC LAN vendors are in many ways crippled by the heritage of an older, single-user technology (the 8088 chip and CP/M, for example). As a consequence of these deficiencies, portions of the PC LAN-vendor market share may be swallowed up as the manufacturers of the UNIX workstation, minicomputer vendors, and other large computer-manufacturing interests bring the full weight of their distributed technologies to bear on the DOS LAN marketplace.

LANS OF TOMORROW

Although LANs have matured enough to become the business solution for workgroup and departmental systems, the industry is less than 10 years old. LAN standards, product interoperability, and vendor stability may take years to develop fully. As the industry grows, market forces will eliminate many LAN products and vendors—the normal shakeout in any maturing industry. LAN evaluators should bear in mind that the technology they embrace today may not be available in years to come.

Evaluating LANs is an increasingly demanding undertaking considering the diversity of technologies and the transitional state of the LAN industry. LAN products that offer the best cost/performance now may prove less viable in the future when issues such as wide area interoperability, standardized communications APIs, and networked management become dominant concerns.

Computer science has created hardware and software advances that could provide users with the services, dependability, and performance they require now. Yet, a substantial gap remains between LAN technologies and what users can purchase.

Although present in many industries, this effect is particularly evident in the computer field where scientific research produces advances in technology much faster than the commercial sector can bring them to market. The gap between capabilities and deliverable products is particularly acute in the PC network field as attempts are made to build powerful distributed systems out of products based on older single-user, single-tasking platforms.

The solution to this problem must lie with the companies that manufacture and market network products. Remarkable opportunities exist for firms that can adapt to the dynamic environment of the LAN industry by delivering innovative products tailored to meet changing needs.

With this in mind, developers should be constantly aware of changes in the LAN marketplace. Integrators and end-user organizations must be equally cautious in assessing connectivity products. As the LAN industry matures and LANs connections multiply, the best efforts of all computer professionals will be required if LANs are to reach their phenomenal potential.

Steven S. King is a technical editor with PC Tech Journal, *specializing in networks. Charles Rose, a network consultant in Washington, DC, contributed to this article.*

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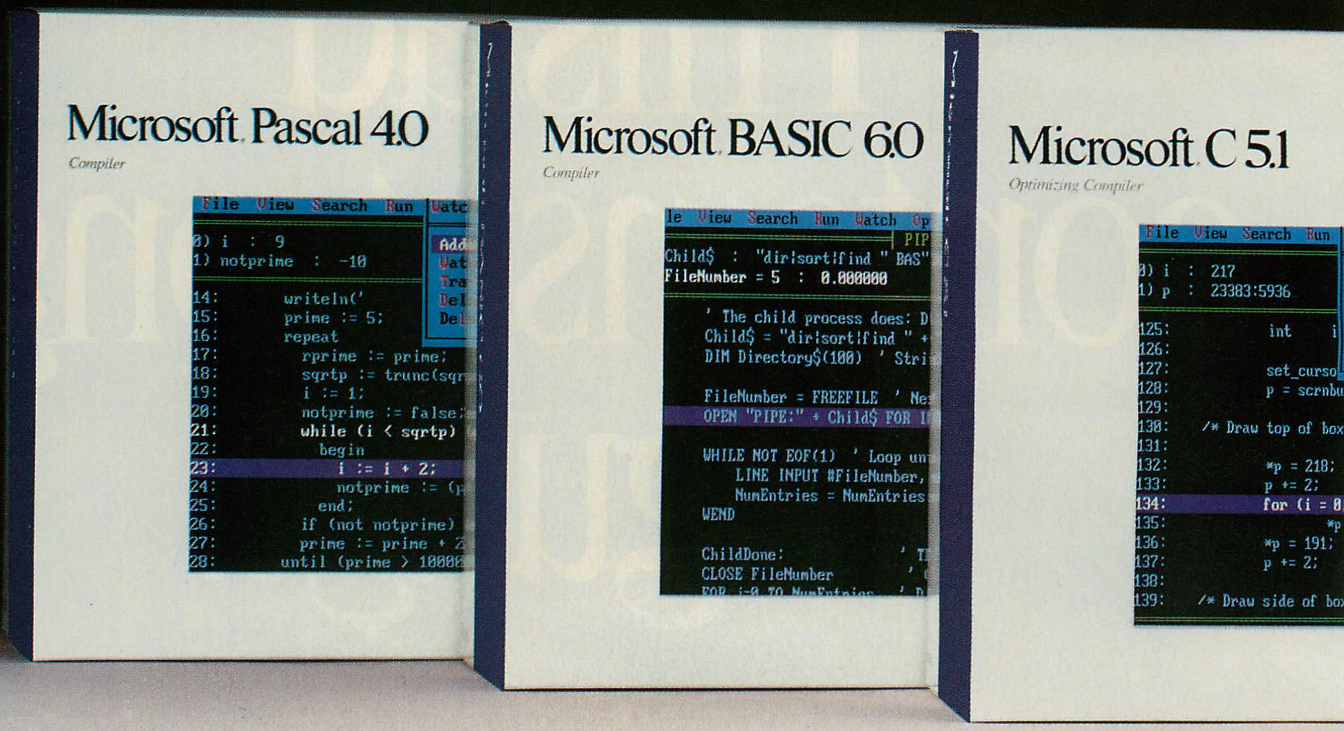

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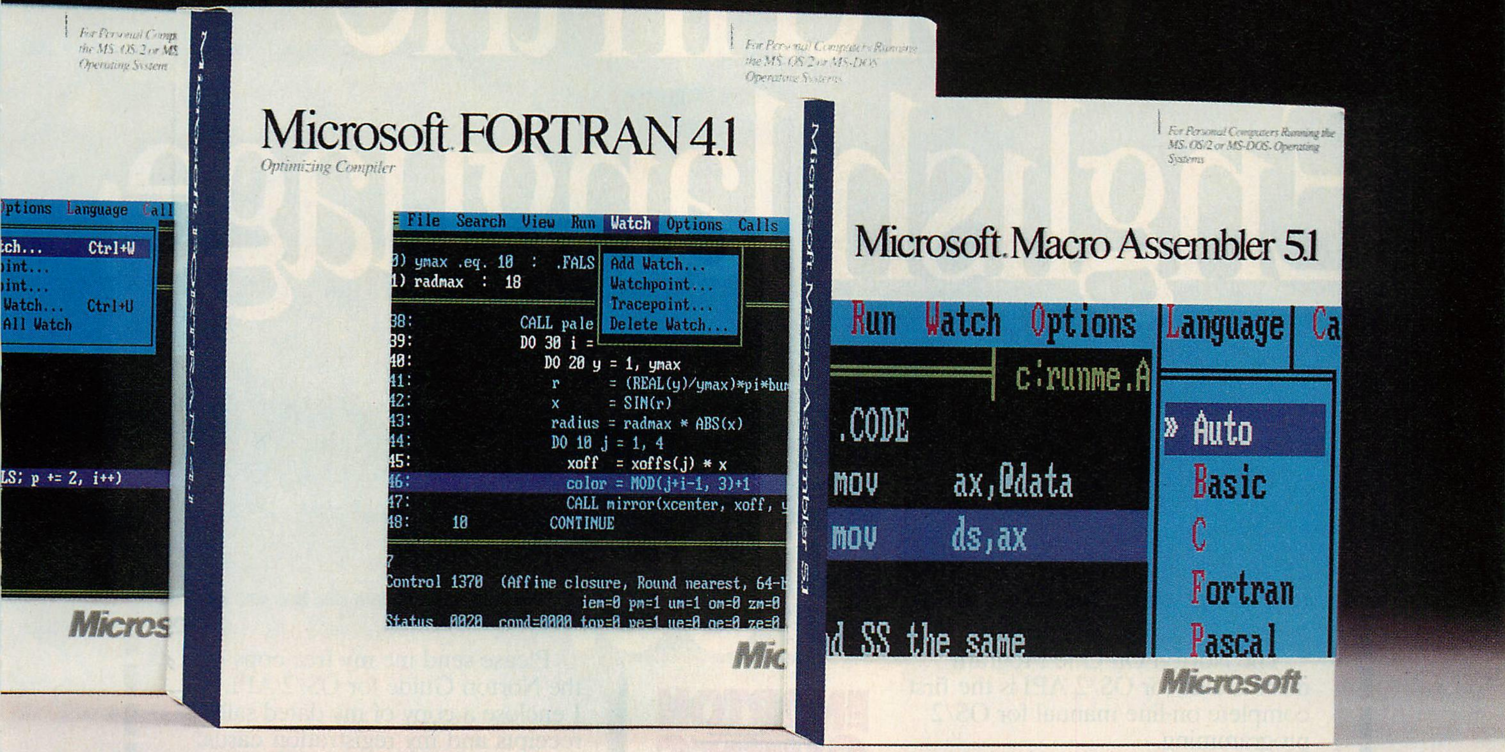

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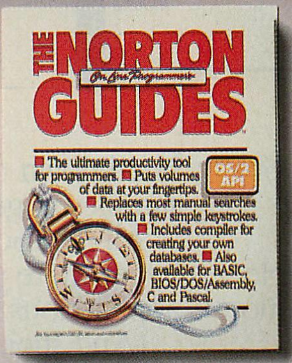

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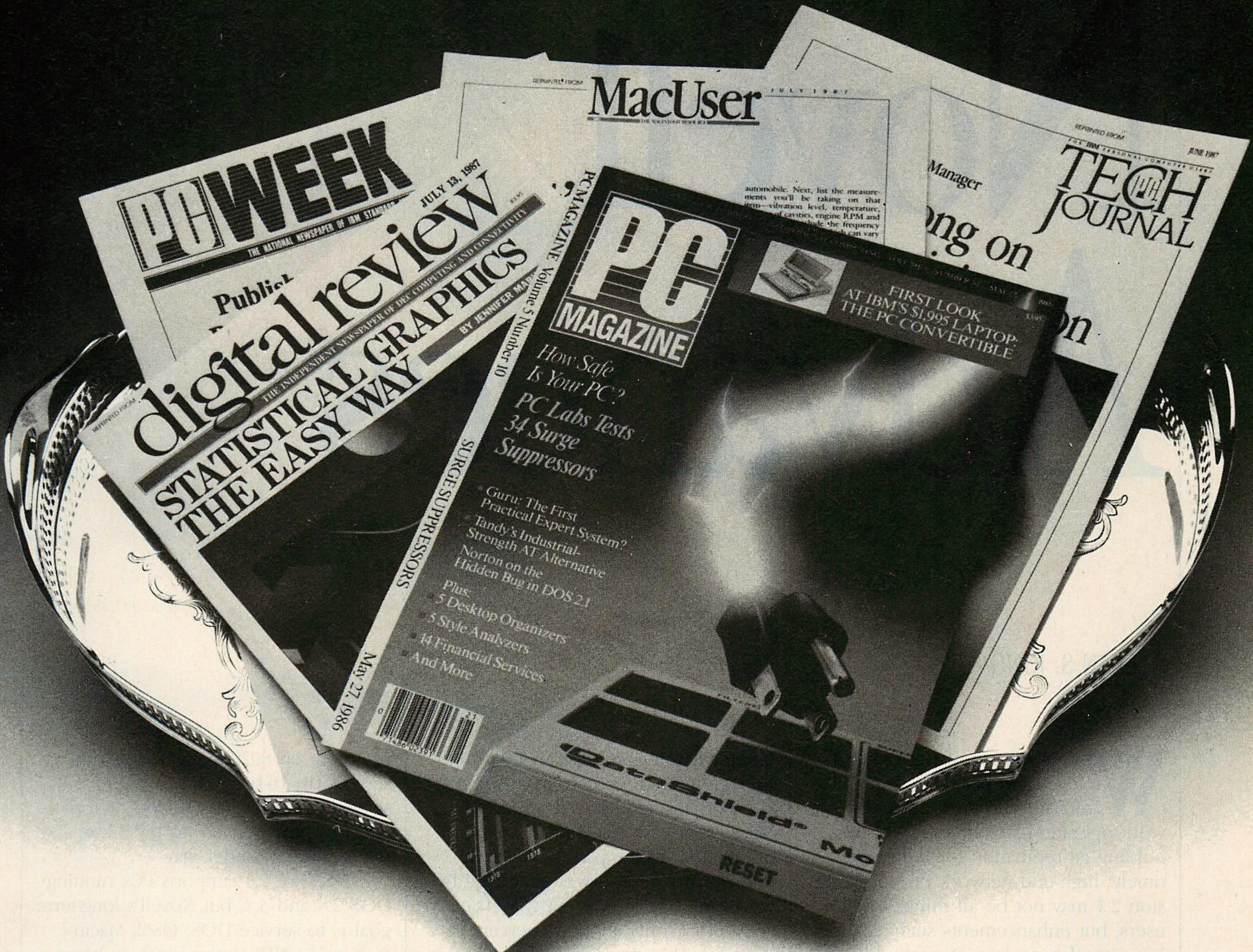

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Novell Advances

STEVEN S. KING

With its release of NetWare 2.1, Novell has taken the lead in offering the most advanced network operating system software, upholding its reputation for delivering timely, high-end network products. Version 2.1 may not be all things to all users, but enhancements such as auditing, virtual consoles, internetwork NETBIOS, and intruder protection address many local area network (LAN) needs.

According to the market research firm DataQuest, Novell is the largest supplier of PC network operating systems, with a 1987 market share of 50 percent. 3Com Corporation was the closest competitor with 15 percent, and IBM had a 10-percent share. Although it has suffered growing pains like any fast-expanding company, Novell has great influence on developers and end users. This is an influence hard won by the company's attention to advancing technology, on-going educational activities, and widely available literature.

This popularity has translated into a phenomenal growth rate for the company. In 1984, Novell's second year of operation since incorporation, gross sales of network products totaled nearly $20 million. Sales for 1988 will exceed $200 million, based on first-quarter earnings in excess of $50 million—a tenfold increase in five years.

Perhaps another reason for Novell's success is a shift in product orientation. In the past, as much as 75 percent of revenues was generated by hardware, but current hardware sales account for only about 45 percent of the total. This change is the result of a corporate goal to move toward a software-oriented revenue base. Novell's future software/hardware ratio is projected at 70/30, says Craig Burton, vice-president of corporate development.

NetWare 2.1 belongs to a family of LAN products from Novell that includes network gateways, database server software, file servers, network interface boards, communications software, and application program interfaces (APIs). The software reviewed in this article is System Fault Tolerant (SFT) NetWare 2.1. SFT versions of NetWare protect users against network failures using duplicate drives, directory structures, disk controllers, and so on. NetWare 2.1 was initially released only in its System Fault Tolerant version.

Originally developed for a long-defunct Z80 file server, NetWare has been ported to the Motorola 68000 and Intel 8086 families. Currently it is most prevalent on 80286- and 80386-class servers (in 16-bit mode), with a substantial base of 68000 servers. Novell's effort to port NetWare to the 32-bit 386 architecture is under way.

NetWare 2.1 supports PCs running DOS 2.x and 3.x, but Novell's long-term goal is to service DOS, OS/2, Macintosh, and UNIX systems in a multivendor environment. (Software for interfacing OS/2 workstations with NetWare servers is in beta test.) Novell is not alone in striving for heterogeneous support of many operating systems on one network; several vendors are developing multiprotocol platforms, but major products of this type will not be widely available until late 1988 or 1989.

NetWare is traditionally associated with support for many different topologies. In the early stages of the LAN industry, when most LAN vendors supported only one topology, Novell's multiple-topology architecture was a major attraction for resellers and end users (see "NetWare in Control," Art Krumrey, November 1985, p. 102).

Today, support for multiple topologies is not remarkable, due in part to wide acceptance of a few access methods—primarily Ethernet, ARCnet, StarLAN, and Token-Ring. As topologies

NetWare 2.1 delivers networking features and administrative services that should promise it a long and useful life cycle, even as the LAN industry progresses steadily.

have matured, Novell has remained a force in the industry by aggressively developing the client services and APIs of its file-server software.

The Novell philosophy of networking places a high value on PC-oriented distributed architectures. This philosophy applies not just to distributed processing on PC stations, but also to distributed network services on specialized servers. With this approach, communications services such as 3270 gateways and modem servers are placed on separate nodes. This can mean an excessive number of servers, but the payoff is that communications server crashes do not affect file services.

MODEL PERFORMER

NetWare's network services fit well into a widely used model for a distributed system that identifies *server* and *client* as the two primary network functions. Servers are network nodes that provide services to clients (end-user stations). The client-server model does not preclude client and server functions from running in the same node.

The NetWare architecture lends itself well to a centralized management scheme. A NetWare *supervisor* manages the file server and its resources, and

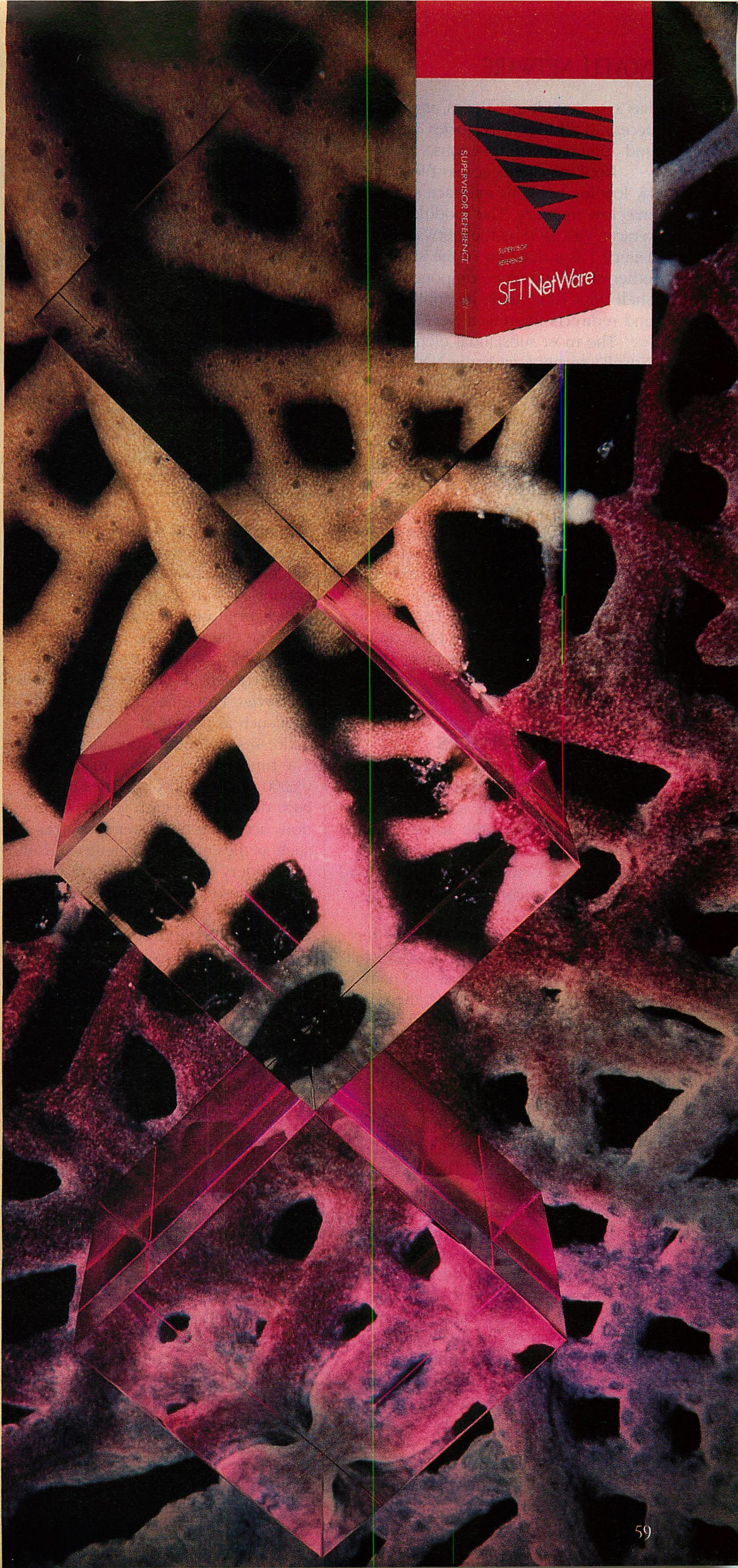

IMAGE • FOUR BY FIVE PHOTOGRAPHY • JOHN LEI

has system-wide privileges, including access to all files, directories, printers, and administrative functions.

NetWare clients access file servers by loading network interface software into low memory. The module that interacts with DOS is the NetWare shell. Figure 1 is a diagram of the shell and other client software components. The shell traps calls made by applications and redirects them to a NetWare server.

The most substantial element of Novell's technology is the NetWare proprietary network operating system (NOS). It provides the low-level routines that manage the processor, memory, and I/O channels. Although NetWare performs hardware management routines similar to DOS and UNIX, it is more highly optimized for network operations. DOS is not present on NetWare dedicated servers and runs only as a guest on nondedicated servers.

NetWare supports multiple server configurations on a single LAN and interconnection of multiple LANs on a single site, with links to remote sites established through leased or switched communication lines.

The extensive NetWare 2.1 documentation is well organized, and, for novice and seasoned administrators alike, Novell provides a *Guide To Manuals* manual.

CONNECTION SERVICES

Security on NetWare servers is excellent. The proprietary nature of the operating system and file structures makes unauthorized file access difficult. Because Novell drives are not DOS-formatted, DOS utilities cannot be used at the server to copy or extract data from them.

Clients who require NetWare services must first connect to a server via login. The SLIST utility lists the names of active NetWare servers on the client's LAN and other connected LANs. Under NetWare 2.1, logins can be restricted to certain times of the day, and a user attempting to log in during a restricted period is denied access.

Each NetWare station has a physical network address associated with its network interface card. The supervisor can restrict a user to logins at specific stations as determined by the physical network address. The system has one loophole, at least for the savvy user. The network address can be changed in the driver software on some network boards—Token-Ring, for example.

Once a server has been selected, the client runs a login utility that accepts a user name and password, then authenticates client access rights by querying a security database on the server called the *bindery*.

Each NetWare server has a bindery, providing a central repository for administrative and security information relating to all network resources. The bindery maintains entries for network entities, such as user, file server, print server, print queue, and group.

The entities in the bindery are called *objects*. The attributes of objects, also recorded in the bindery, are called *properties*. Properties are comprised of data such as passwords, internetwork addresses, and other identification data. The bindery files store as many as 65,000 objects and properties in a secure directory on each server. Operations accessing file-server resources such as files and print queues consult the bindery for security information.

Because all logins are verified with a check of the bindery, NetWare servers are generally safe from illegal logins. Passwords passed from client to server are encrypted at the workstation. Encryption defeats attempts at listening for passwords on the network cable with a device such as The Sniffer from Network General (see "Analyzing Network Traffic," J. Scott Haugdahl, October 1987, p. 48, for a review).

FILE SERVICES

NetWare enhances DOS with additional file attributes and security, thus providing better control over files and directories. NetWare enhancements include 255MB disk-volume sizes, a maximum 32,000 directory entries per volume, and 1,000 concurrent open files per server. Novell provides support for large servers—up to 32 drives, 3GB of storage, and 12MB of system RAM.

The files and directories of a NetWare disk volume are located in one directory structure. This directory structure can grow quite large, containing thousands of subdirectories and tens of thousands of files, without becoming disorganized. The NetWare approach is similar to the UNIX file system in this respect, except that UNIX systems allow directory structures to span drives (Novell does not).

NetWare extends the usefulness of its file system by allowing clients to assign any subdirectory to any drive designator from A: to Z:, using the NetWare MAP utility. MAP works similarly to DOS SUBST. With the exception of diskless computers, client stations require the first few drive designators for local drives—A:, B:, C:. NetWare drive designators normally begin after the local drives, using drives F: through Z: for network drives. If necessary, all 26 drive designators from A: to Z: can be simultaneously assigned to a different subdirectory in the directory system.

Searching for data. NetWare allows multiple search directories, similar to DOS PATH. Users can designate as many as 16 drives on a client station as search drives. Directories assigned to a search drive are searched when DOS looks for .EXE, .COM, and .BAT files to execute. NetWare also checks search directories during any file-open operation (like DOS APPEND) when the file is not found on the default drive.

File attributes. NetWare supports 10 general-purpose file attributes that can be set from the command line using the FLAG command, or with FILER, NetWare's file-management utility. FILER lets users copy, move, rename, and delete any files or directories to which they have access, and on any server. FILER reports file system information such as file attributes, file creator, remaining bytes of storage, and remaining directory entries.

NetWare file attributes are a superset of DOS file attributes and include read-only, read-write, shareable, non-

shareable, hidden, archive, system, indexed, execute-only, and transactional.

Shared program files are usually set to shareable, read-only in the NetWare environment. Files opened with the DOS extended open mode (deny-none) can be accessed concurrently by multiple users, regardless of their NetWare file attribute; the DOS open modes take precedence.

NetWare builds a file allocation table (FAT) for the entries of files with the index attribute set. This is especially useful for large files whose FAT pointers take excessive time to search sequentially. Indexed FAT lookups take place in a fraction of the time required for a nonindexed FAT. Novell recommends FAT indexing for files of 10MB or more. Each FAT index (one per file) requires 1KB of RAM in the server and can be shared by multiple clients accessing the same file.

An execute-only attribute provides copy protection for applications running on NetWare servers; it specifies that a file may be opened for execution, but may not be copied. Files with .EXE and .COM extensions are assigned the execute-only attribute by the network supervisor. NetWare implements this feature by allowing the command processor—and no other process—to open execute-only files. This works fine for programs that do not open their executable file after load time. Unfortunately, programs that need to read their executable file after loading will not run with the execute-only attribute.

Trustee and directory rights. NetWare supports a highly structured system of user access rights in its file system. Users may have rights to any directory or group of directories, depending on their needs. NetWare directory access rights are stored as fields embedded in the directory tables and do not exist as separate files that could be tampered with. Because the rights are built into the file system, NetWare can ensure they are verified during every file operation. Many of the access restrictions regard the directory as the basic unit of security. To access the files in a directory, a user must be assigned trustee rights to the directory.

NetWare users cannot list the file names in a directory without trustee rights. An attempt to list files without rights will return "file not found." However, users can view the directory names for any directory on the system with or without rights. Considering that directory names themselves may have significance, this may be undesirable. Ideally, users who have no rights to a directory should see neither file nor subdirectory names.

As part of its system for fault tolerance, NetWare maintains duplicate directory structures for each disk volume. To ensure data integrity, directories are verified each time the system is initialized, and if a FAT is corrupted, a backup copy is available.

PRINT SERVICES

File services are of limited usefulness without ample print services. The NetWare 2.1 print services support features normally associated with larger systems—support for multiple printers, print queues, print job configuration utilities, remote printer consoles, and multiple print console operators.

Unfortunately, NetWare does not support dedicated print servers or shared printers on client stations. Although clients can print to their own local printers, NetWare 2.1 requires that all *shared* printers be connected to the file server. This limits the number of shared printers to five for AT-type servers and may also restrict their location, considering a cable must run from each printer to the file server.

At the core of Novell technology is the NetWare proprietary network operating system, which is highly optimized for LANs.

Novell has encouraged third-party vendors to develop print servers, and many enhancements to NetWare print services are available. Brightwork Software (formerly Westcon Associates), for example, makes PS Print, a system for Novell LANs that increases the number of shared printers with dedicated and nondedicated print servers.

The user can submit print jobs in several ways. The NetWare shell can capture print output from applications and redirect it to network printers on the server. Output for LPT1, LPT2, or LPT3 can be redirected. Alternatively, applications that are written for NetWare, such as WordPerfect, can make NetWare extended function calls that send print jobs directly to the server, bypassing DOS print services. With a third method, users may send files formatted for printer output from the command line using the NPRINT command, which prints one or more print files to a designated printer on any accessible server.

NetWare extends its file-server security scheme to the print queues and printers. Users must be given access rights to each print queue they access. Queue access rights, incorporated in the bindery, are strictly enforced.

The improvements in NetWare 2.1 print services are impressive, but ideally the queue and job management functions should be written into applications such as word processors and databases. Many of the 2.1 print features are new to NetWare and have not yet been widely incorporated into network applications. Because Novell's print service function calls are specific to NetWare, developers must customize their software to NetWare, or users will be forced to exit their application to manage print services.

COMMUNICATIONS SERVICES

Although NetWare's strengths are concentrated in its file, print, and administrative services, some communications services are included with version 2.1 as well. Its most basic form of communication is the SEND utility. SEND is invoked from the command line and sends a one-line message from one station to another. Messages can be sent to a single user, a group of users, or everyone logged onto the LAN. For most intra-LAN communications needs, though, SEND is too rudimentary.

Novell also supplies an electronic mail (E-mail) program with NetWare 2.1; it supports some useful features, but is awkward for the average user. Novell has made no enhancements to the program in recent versions and says it will not develop this package further. Full-featured E-mail products from third-party vendors are available for Novell LANs (see "E-Mail Arrives," Parts 1 and 2, Steven S. King, April 1988, p. 106 and May 1988, p. 118). In addition, Novell markets Action Technology's Coordinator, which provides E-mail and other work-group productivity services.

Gateways and modem servers. Several products for wide area communications may be purchased separately from Novell. Products compatible with NetWare 2.1 include gateways to IBM 3270, IBM 5250, and X.25 environments. These products are developed by CXI Inc., a company recently acquired by Novell. A NetWare Asynchronous Communication Server (ACS) furnishes network users with a pool of shared mo-

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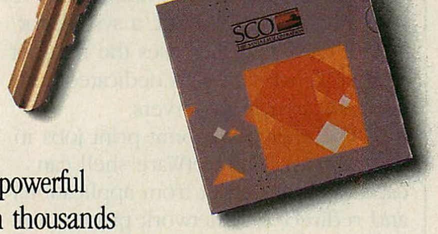

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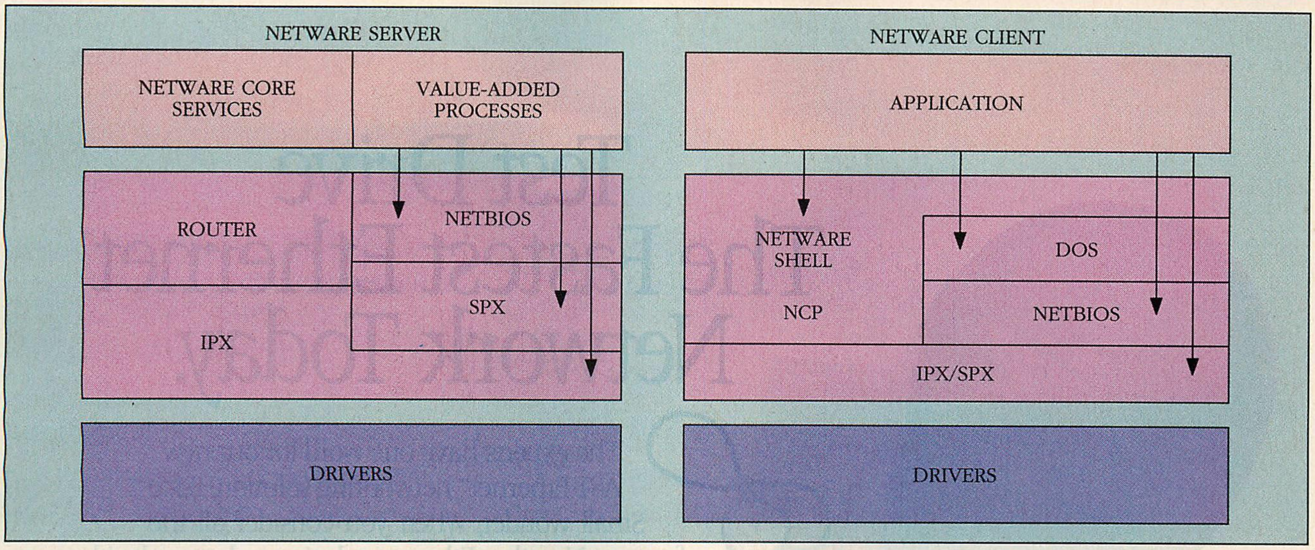
CIRCLE NO. 117 ON READER SERVICE CARD

FIGURE 1: ***NetWare Block Diagram***



In a typical NetWare protocol stack, applications can make calls (indicated by arrows) to various system and communication layers. On the client side, an application calls DOS, NETBIOS, IPX/SPX, or the NetWare shell. The server stack includes a third-party value-added process running in the server to supplement the NetWare Core Services.

dems, eliminating the need for every station to have its own. The server runs in a dedicated PC and supports as many as 12 modems on a single network node.

Clients of the ACS run a program called ASCOM, from Dynamic Microprocessor Associates, that directs communications data through the network to the ACS, where it is forwarded to an available modem. The ports on the ACS also can be hard-wired to local hosts that support asynchronous communications. Outgoing ACS sessions emulate terminals from companies such as Digital Equipment Corporation (DEC), TeleVideo, and Hewlett-Packard (HP). The ASCOM user interface is very different from the interface to the NetWare administrative utilities, and nontechnical users may find it difficult to learn.

Numerous third-party vendors offer communications products for NetWare, including X.25 and 3270 gateways, modem-sharing software, high-speed bridges, and wide area messaging systems. Although each product introduces a new user interface and can require substantial integration efforts, they are valuable because they meet needs that Novell (or any single company) cannot meet by itself.

ADMINISTRATION ADVANCES

With the NetWare administration utilities, the supervisor establishes user accounts and manages server resources, such as printers and the file system. Administration is one of several areas in which Novell strives to provide the advanced management features found on minicomputers and mainframes. The execution of these features is sometimes rudimentary, but should improve as suggestions from users are incorporated.

SYSCON. This is the one utility used most by NetWare supervisors for managing user accounts, billing, security, and adjusting parameters affecting workstation initialization and server access. SYSCON queries and updates the security data in the bindery in the course of its management activities. A user's account stores login name, login restrictions, login password, full name, group affiliations, disk-space allocation, and other accounting information.

Limiting disk usage is one of the most important new administrative features of SFT 2.1. In previous versions, NetWare allocated disk space to all users in an unrestricted manner. One user could fill the entire disk volume, unintentionally or otherwise. The new disk-limit feature is invaluable for system administrators plagued by users who do not archive and delete files. Disk space limits put a ceiling on each user's storage that can be designated individually or across an entire system.

As important as it is, the new feature is implemented somewhat oddly—it can be enabled only during the generation of the operating system. And worse, when a system-wide, disk-space limit is set as a default, the restriction affects only those user accounts made after the limit is set. This implementation will make it difficult for system managers to change their minds about the optimum disk-space limits because a changed limit will apply only to new accounts. Consequently, most supervisors will set limits individually.

One of SYSCON's primary functions is resource accounting. It enables the supervisor to allocate system resources and bill for their use. System resources are identified as disk block reads, disk block writes, connect time, disk storage, and service requests. The billing function is based on a monetary charge that is set for each user. These charges can vary within time ranges for each day of the week—higher for peak traffic periods and lower for other times. In the accounting charge screen shown in photo 1, higher charges have been entered for business hours and lower charges for weekends and evenings.

Charge figures are entered into the SYSCON entry screen, which accepts integers, but not decimals. This may be frustrating for end users, because charge values are normally in fractions of a cent for operations such as block reads and service requests. The charge rates can be set dynamically by the supervisor and converted to dollars and cents external to the system. Multiplier and divisor figures may be entered to achieve better precision.

When charges are set, each user's account is assigned a credit balance, which is debited each time system resources are accessed. When the user's credit limit is exceeded, access is suspended (gracefully) until the supervisor

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assigns more credit. The accounting system can allow the user a grace period so that system continues even after the credit limit is exceeded.

As might be expected in a first release, accounting reports are minimal in NetWare 2.1. The accounting data are stored in files in the supervisor's directory. The two utilities provided do minimal reporting: PAUDIT dumps the entire contents of the audit log to the screen, sequentially, and ATOTAL produces a summary report of resources utilization, by day and week. Neither of these reports is sufficient for a detailed analysis of file-server usage. Novell advises end users and independent software developers to write programs to format and output the NetWare accounting data.

The intruder lockout function tracks the number of login attempts with incorrect passwords. The supervisor can set a threshold of sequential unsuccessful attempts that trigger intruder lockout. When lockout occurs, the account is disabled and further login attempts are denied—with or without the correct password. The duration of the lockout, generally 10 to 20 minutes, is set by the supervisor. Incidents of unsuccessful login attempts are reported for each user account.

This type of security is often found on large, centralized systems. It foils intruders who attempt break-ins using software that automatically generates large numbers of login attempts, each with different passwords. NetWare 2.1 also allows an account to be disabled temporarily when a user is away for a period of time. The supervisor also can set an account expiration date for any account with a limited lifetime.

NetWare password-management functions have improved considerably with version 2.1. Users still create their own passwords, but the supervisor determines the minimum number of characters in a password. The new password system can require that users change their passwords periodically and always use a unique password.

FCONSOLE. NetWare's new virtual console utility, FCONSOLE, provides a wealth of realtime statistics for system servers. Statistics are reported on file-server components, such as disk caches, disk channels, file system, transaction tracking, and packet delivery. Running totals of file-server operations are kept for each of these areas.

Photo 2 shows the File Server Statistics Summary screen, one of many screens in the FCONSOLE system. These summary statistics give an indication of the effectiveness of the file server's operations—for example, the percentage of cache hits is a good measure of system response time. If the file-cache hit percentage is low (below 80 percent), the system is going to disk too often and additional server memory may be required. Depending on the type of file I/O, 90 percent or more of NetWare disk requests can be serviced from cache memory.

Cache buffers are 4KB each; any system RAM left after the operating system is loaded is automatically allocated to file caching. In the summary screen

Internetworking capability is built into the NetWare file, print, and administrative services. Bridges are located in servers or dedicated PCs.

(photo 2), the server has 1,149 cache buffers—more than 4MB of cache memory. NetWare servers supporting disk-intensive applications can support 6MB or more total cache space.

The three dynamic memory pools on the bottom of the screen store operating system tables that track active drives, directory handles, connections, and so on. The Current-Server-Utilization figure at the top of the screen is a measurement of system idle time; a higher percentage indicates less idle time, hence higher utilization.

A NETWORK OF NETWORKS

Internetworking capability is built into the NetWare file, print, and administrative services. NetWare can interconnect LANs via bridges in file servers or dedicated PCs. A NetWare *bridge* is the equivalent of a *router* in Open System Interconnection (OSI) terminology and operates at the network level (the third layer of the OSI model).

NetWare bridges are managed by router software that knows the addresses of other routers on the internetwork. Router software blocks packets that do not need to pass through a bridge, based on the address header in each packet. A single bridge may connect a maximum of four similar or dissimilar networks. For example, a number of servers, each supporting its own local ARCnet, can be connected with a high-speed Ethernet backbone. In this configuration, router software on servers directs packets into the backbone only if necessary.

NetWare has an enormous capacity for combining dissimilar topologies. The network drivers diagrammed in figure 1 are the only software that varies between topologies; the higher-level protocols remain the same. Mixing dissimilar topologies sometimes makes networks more difficult to diagnose and maintain, but is more cost effective than running high bandwidth links to every station.

A NetWare bridge or server can accommodate four network adapters, but some board combinations conflict and force this number lower. For example, up to three 3Com 16-bit 3C505 boards can be configured in a bridge or server, but 3Com's 8-bit 3C501 boards yield only two nonconflicting interrupt settings. IBM Token-Ring boards must be strapped as primary or secondary, so two, at most, are supported in one machine. One workable configuration of four boards would be: two Standard MicroSystem ARCnet cards, one Token-Ring board, and one 3Com 3C505 board. A server accommodating this arrangement would support two independent ARCnet networks, a Token-Ring, and an Ethernet.

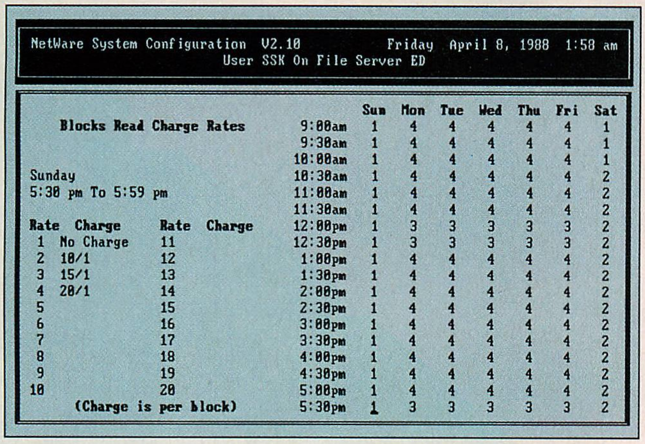
The usefulness of multiple cards in a server increases as the speed of the cards decreases. Low-speed cards throttle the server, delivering a network bandwidth that is less than the maximum available throughput of the server. See the sidebar "Consistent Performance" on page 70 for details. Because of their high throughput, NetWare servers are particularly susceptible to throttling. Adding cards to a server in this case allows the server to reach its maximum throughput.

For higher-speed boards, such as Ethernet, adding boards does not increase server throughput because a single board delivers a bandwidth that exceeds server throughput.

NetWare remote bridges connect networks on different sites with voice-grade-or-better telephone connections. They were sold separately in previous versions, but are bundled with the operating system in NetWare 2.1.

Like Banyan and 3Com, Novell supports bridges in its file servers; but unlike those vendors, Novell does not recommend its file-server bridges for demanding applications because they degrade the performance of file and print services. Although NetWare's file-server performance is at the top of its class, Novell has not integrated the

PHOTO 1: *Accounting Charge Screen*

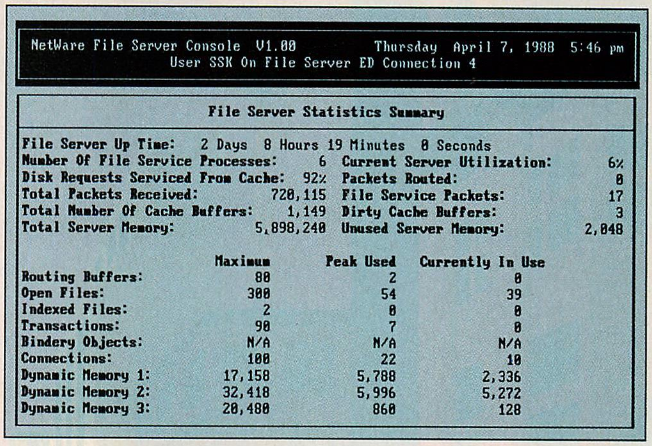


```
NetWare System Configuration  V2.10          Friday  April 8, 1988  1:58 am
                      User SSK On File Server ED

                                                Sun  Mon  Tue  Wed  Thu  Fri  Sat
     Blocks Read Charge Rates          9:00am    1    4    4    4    4    4    1
                                       9:30am    1    4    4    4    4    4    1
                                      10:00am    1    4    4    4    4    4    1
Sunday                                10:30am    1    4    4    4    4    4    2
5:30 pm To 5:59 pm                    11:00am    1    4    4    4    4    4    2
                                      11:30am    1    4    4    4    4    4    2
Rate  Charge        Rate  Charge      12:00pm    1    3    3    3    3    3    2
 1  No Charge        11               12:30pm    1    3    3    3    3    3    2
 2  10/1             12                1:00pm    1    4    4    4    4    4    2
 3  15/1             13                1:30pm    1    4    4    4    4    4    2
 4  20/1             14                2:00pm    1    4    4    4    4    4    2
 5                   15                2:30pm    1    4    4    4    4    4    2
 6                   16                3:00pm    1    4    4    4    4    4    2
 7                   17                3:30pm    1    4    4    4    4    4    2
 8                   18                4:00pm    1    4    4    4    4    4    2
 9                   19                4:30pm    1    4    4    4    4    4    2
10                   20                5:00pm    1    4    4    4    4    4    2
     (Charge is per block)             5:30pm    1    3    3    3    3    3    2
```

This charge rate screen is part of the new NetWare 2.1 accounting services. It specifies the charge rate for each disk block read by user SSK. Rates have been set higher during peak business hours. The actual charges for server access are given in integer values and converted to dollars and cents external to the accounting system.

PHOTO 2: *FCONSOLE Server Statistics*



```
NetWare File Server Console  V1.00        Thursday  April 7, 1988  5:46 pm
              User SSK On File Server ED Connection 4

                    File Server Statistics Summary

File Server Up Time:   2 Days  8 Hours 19 Minutes  0 Seconds
Number Of File Service Processes:      6  Current Server Utilization:      6%
Disk Requests Serviced From Cache:   92%  Packets Routed:                   0
Total Packets Received:          720,115  File Service Packets:            17
Total Number Of Cache Buffers:     1,149  Dirty Cache Buffers:              3
Total Server Memory:           5,898,240  Unused Server Memory:         2,048

                          Maximum       Peak Used    Currently In Use
Routing Buffers:               80               2                   0
Open Files:                   300              54                  39
Indexed Files:                  2               0                   0
Transactions:                  90               7                   0
Bindery Objects:              N/A             N/A                 N/A
Connections:                  100              22                  10
Dynamic Memory 1:          17,158           5,788               2,336
Dynamic Memory 2:          32,418           5,996               5,272
Dynamic Memory 3:          20,480             860                 128
```

The top part of this screen supplies the NetWare supervisor with realtime traffic and usage statistics for the file server. The bottom of the screen gives server maximums, as they were set when the operating system was generated, and the degree to which these maximums are being approached (Peak Used and Currently In Use).

low-speed communications necessary for wide area networking.

When possible, the NetWare bridge should be a dedicated PC. However, nondedicated PCs are also supported and require 160KB of memory for bridge software; if a user hangs a nondedicated bridge, remote sessions supported by the bridge will be terminated, with possible data loss for all involved. NetWare remote bridges can be synchronous or asynchronous and use one or two modems connected to COM1 and COM2. Modem speeds range from 1,200 bits per second (bps) to 19.2 Kbps, making high-speed links with modems such as the Telebit TrailBlazer possible.

Bridges that connect remote networks run in two modes. With *permanent* mode, the bridge connection is maintained at all times. In *timed* mode, a connection is created when it is requested by a user. Timed bridge links are automatically disconnected after a predetermined number of minutes, from 1 to 59.

Synchronous bridges also are supported in NetWare 2.1, but require the additional purchase of a high-level data link control (HDLC) board. Synchronous remote bridges run at maximum speeds of 64KB per second and can take advantage of X.25 packet-switching networks and leased lines.

PROTOCOL LAYERS

In a break from earlier versions of NetWare, version 2.1 network drivers are not linked into the workstation's shell. The shells are now in a separate executable file, and the subnetwork software, IPX/SPX (internet packet exchange/sequenced packet exchange), links to the driver and is loaded from a file called IPX.COM (see figure 1). An exception to this procedure is IBM Token-Ring, which requires the manufacturer's driver loaded in addition to IPX.COM. Novell does not support an 802.2 LLC layer for its Token-Ring, Ethernet, and StarLAN drivers; drivers interface indirectly with the IPX/SPX module. This means programmers cannot write to a common link layer for 802 topologies.

IPX corresponds to the OSI network layer and supports internetwork routing and nonguaranteed packet delivery. SPX, which corresponds to the OSI transport layer, enhances IPX services with packet sequencing and guaranteed packet delivery. Both of these protocol layers are derivatives of the Xerox Network Systems (XNS) internetwork protocol specification.

The NetWare shell uses only IPX services to communicate with the file server because shell processes have their own internal retry and error-recovery routines. SPX is not used by the shell and is loaded at the workstation to provide client applications with a transport layer interface. Client applications require SPX guaranteed delivery and flow control when they communicate with nodes that have long or unpredictable response times, such as communication gateways and database, optical-disk, or archive servers.

Novell has implemented a NETBIOS emulator for interprogram communications, on top of IPX protocols. Applications use NETBIOS services to conduct interprocess communication with other NetWare nodes only. NETBIOS protocols from other vendors use different subnet components and are not compatible.

Prior to version 2.1, the NetWare NETBIOS emulator did not support internetworking. This meant that 3270 gateways and other NETBIOS-based servers could not be reached through internetwork bridges. NetWare 2.1 adds this support, but with some qualifications. NETBIOS was designed for single LANs, not large internetworks. To register a name, NETBIOS must broadcast the name to all nodes to check for uniqueness. The traffic associated with broadcasts to all nodes on large internetworks is excessive and monopolizes the network.

Early versions of Novell's NETBIOS emulator avoided the broadcast problem by blocking broadcasts at bridges (NetWare routers). NetWare 2.1 compromises by initially letting broadcasts pass through bridges to establish a session, but it does not allow broadcasts after a session has been established. To avoid congestion of remote links, NetWare routers block NETBIOS broadcasts at low-speed bridges at all times.

Although NetWare NETBIOS checks for name uniqueness when initializing, there is one situation in which identical names may exist on an internetwork. Two unconnected networks may have identical NETBIOS names established and become connected at some later time. If this happens, communications

QNX vs. OS/2 UNIX

QNX: Bend it, shape it, any way you want it.

ARCHITECTURE If the micro world were not so varied, QNX would not be so successful. After all, it is the operating system which enhances or limits the potential capabilities of applications. QNX owes its success (over 55,000 systems sold since 1982) to the tremendous power and flexibility provided by its modular architecture.

Based on message-passing, QNX is radically more innovative than UNIX or OS/2. Written by a small team of dedicated designers, it provides a fully integrated multi-user, multi-tasking, networked operating system in a lean 148K. By comparison, both OS/2 and UNIX, written by many hands, are huge and cumbersome. Both are examples of a monolithic operating system design fashionable over 20 years ago.

MULTI-USER OS/2 is multi-tasking but NOT multi-user. For OS/2, this inherent deficiency is a serious handicap for terminal and remote access. QNX is both multi-tasking AND multi-user, allowing up to 32 terminals and modems to connect to any computer.

INTEGRATED NETWORKING Neither UNIX nor OS/2 can provide integrated networking. With truly distributed processing and resource sharing, QNX makes all resources (processors, disks, printers and modems anywhere on the network) available to any user. Systems may be single computers, or, by simply adding micros without changes to user software, they can grow to large transparent multiprocessor environments. QNX is the mainframe you build micro by micro.

PC's, AT's and PS/2's OS/2 and UNIX severely restrict hardware that can be used: you must replace all your PC's with AT's. In contrast, QNX runs superbly on PC's and literally soars on AT's and PS/2's. You can run your unmodified QNX applications on any mix of machines, either standalone or in a QNX local area network, in real mode on PC's or in protected mode on AT's. Only QNX lets you run multi-user/multi-tasking with networking on all classes of machines.

REAL TIME QNX real-time performance leaves both OS/2 and UNIX wallowing at the gate. In fact, QNX is in use at thousands of real-time sites, right now.

DOS SUPPORT QNX allows you to run PC-DOS applications as single-user tasks, for both PC's and AT's in real or protected mode. With OS/2, 128K of the DOS memory is consumed to enable this facility. Within QNX protected mode, a full 640K can be used for PC-DOS.

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Multi-Tasking	64 (150) tasks per PC (AT).	**Flexibility**	Single PC, networked PC's, single PC with terminals, networked PC's with terminals. No central servers. Full sharing of disks, devices and CPU's.
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CIRCLE NO. 181 ON READER SERVICE CARD

can become unpredictable. This is not so much a Novell problem as a NETBIOS problem, and will continue until the NETBIOS standard is extended to encompass internetworking and global naming.

NETWARE INTERNALS

Above the IPX/SPX communications layers resides the NetWare shell. Novell and other vendors use network shells to improve performance and increase functionality. When the shell is loaded, it revectors the DOS interrupt (INT 21H) to its own address space, terminates, but stays resident. Application calls to INT 21H are subsequently hooked by the shell, parsed, and analyzed. If the call is for a local resource, it is passed on to the DOS call handler. If the shell determines the call is for a network resource, it handles the call.

In addition to INT 21H, the shell hooks the following interrupts: INT 8H (timer), INT 10H (video services), INT 17H (printer services), INT 20H (program terminate), INT 24H (critical error handling), and INT 27H (terminate and stay resident). To interact well with DOS and application software processes, the shell must know when these interrupts are in use.

One drawback to network shells is the incompatibility that arises between the shell and DOS when DOS is upgraded. The NetWare shell has extensive hooks into DOS, so Novell must upgrade it whenever DOS is upgraded. Fortunately for NetWare users, shell upgrades have been available whenever DOS has had a major upgrade.

An alternative to using shells is to access network resources through DOS and the Microsoft Network (MS NET) redirector. Companies such as 3Com, HP, and Torus license the redirector for their networks. IBM also employs MS NET for its PC Network and Token-Ring LANs. DOS compatibility is assured under this method; however, network functionality and performance suffer in the process.

With the advent of OS/2, LAN vendors can provide access to servers with operating system calls. Novell's OS/2 client requester, released to developers in February, is implemented with the dynamic link library. Novell's OS/2 requester is supported with the 2.1 version of NetWare only and can coexist with DOS clients.

NetWare Core Protocol. In addition to directing DOS requests to the server, the shell provides "NetWare-aware" applications with function calls to access the extended client services. These calls are defined by the NetWare Core Protocol (NCP), a client-server interface that is similar to MS NET's Server Message Block (SMB). SMB is the dominant client-server interface for PC LANs, but NCP is a more advanced protocol.

NCP is well documented and open to programmers, but it essentially is a Novell proprietary protocol. Some low-end LANs support Novell data management calls, but NCP is not licensed by third-party LAN vendors as is SMB and Sun Microsystem's DFS. SMB is used by IBM, 3Com, AT&T, and other LAN vendors that use the MS NET redirecter.

NetWare's request-response architecture has less overhead than the time-slicing preemptive task manager used by UNIX and OS/2.

SMB is picking up support in the minicomputer industry as well and is currently available on DEC, HP, and other minicomputers.

Although it represents an industry standard, SMB defines fewer than 50 network functions, while NCP defines more than 150. Because of the small number of functions it supports, SMB limits the effectiveness of the redirecter, and MS NET in general. Future enhancements to SMB are anticipated, specifically in connection with Microsoft's LAN Manager, and redirecter services will continue to improve.

This situation is made somewhat tolerable because developers can write applications with standard DOS 3.1 (or later) calls and run in both NCP and SMB environments. For applications that do not need the NCP enhancements, this may be safest.

After an NCP is processed by the shell, it is passed through the communications subsystem to the server. Incoming requests initiate a process on the server that corresponds to the function called at the station. These processes, which Novell refers to as *request-server-processes*, are the workhorses of the NetWare server environment. They manage file system accesses, print jobs, routing, security, and many other critical server functions.

NetWare implements its server processes in a request-response architecture that does not switch processes preemptively. The nonpreemptive approach requires queued server processes to wait until the preceding process yields control before gaining access to server resources. When a process takes control, it must complete its task as soon as possible and relinquish control of server resources to the next server-process. Typically, a server-process quickly spins off a lower-level operation, such as a disk access, and then "goes to sleep" until the low-level operation is complete.

This architecture has the advantage of less overhead than the time-slicing preemptive task manager used by UNIX and OS/2. The trade-off for the performance gain is a potential hazard that processes will take an excessive amount of time returning control to the event scheduler. In this environment, processes must be aware of system timing parameters and be very dependable. In the absence of a preemptive task manager, Novell uses a very small (4KB) multitasking executive (compare this to the total size of the NOS in file server memory, which is close to 400KB).

The NetWare executive is analogous to a very small traffic cop directing large, fast-moving trucks in a busy intersection. In this analogy, the trucks are the request-server-processes transporting data and servicing client requests. These activities normally take place with precision orchestration, but if something goes wrong with a request process in this nonpreemptive environment, the small executive can do nothing. It is to Novell's credit that the file-server processes are very reliable and do not crash headlong at the file-server intersection.

PROGRAMMING UNDER NETWARE

The operating system on the NetWare server is not DOS or a DOS derivative; consequently, its compatibility with DOS is a constant concern. This is particularly true now that DOS has extended its file-access calls to include support for the network environment.

NetWare 2.1 supports all DOS INT 21H functions, including extended file opens, older compatibility opens, and file-locking operations. Modes associated with extended file opens take precedence over the Novell sharing scheme. For example, even if a Novell file is set as nonshareable, multiple clients may open it with the DOS nonexclusive open. Conversely, if an application opens a file that is Novell shareable with a deny-read-write, subsequent opens will be denied. NetWare assumes

that DOS extended open-file operations are made by applications that know how to manage files in the network context.

In addition to support for the DOS file access and locking calls (INT 21H, function 5CH), NetWare provides several of its own data management functions. Records can be locked with byte-offset values or with logical names. Applications that synchronize data access with logical record locks must be coordinated and use the same naming conventions. The NetWare operating system can guarantee only the integrity of data accessed with byte-range locks. Enhanced functions designate groups of files or byte ranges as a resource set that can be locked and released in a single operation.

NetWare manages database file accesses with its Transaction Tracking System (TTS), which views sequences of database operations—lock record, update record, release record—as a single transaction. In the event of a client crash or program abort, TTS discards an unfinished transaction to avoid corrupting the database with incomplete updates. When a program aborts in the course of a transaction, TTS invalidates the incomplete transaction and rolls back to the previous point of database consistency.

TTS has two modes, implicit and explicit. Implicit mode applies to applications that have not been written to take advantage of NetWare TTS. For these applications, TTS assumes that a transaction begins with a lock operation and ends with an unlocking operation. Although implicit transaction tracking works with most multiuser applications that use standard DOS locking calls, cases may arise in which TTS cannot imply which operations constitute a transaction.

Novell has indicated that one of the target applications for implicit TTS is Ashton-Tate's dBASE. Even with dBASE, TTS may have problems implying transactions and will need parameters adjusted. Some versions of dBASE make a locking call during the copy-protection

CONSISTENT PERFORMANCE

Novell file servers are acknowledged to provide some of the best network performance in the industry. Past tests by the press and independent parties have determined that NetWare outperforms other LANs for all but small file operations associated with data management applications. Novell has added local file-caching capabilities to its 2.1 shells, improving performance markedly for operations using small block sizes. When tested with the new shells, NetWare delivered uniformly high performance for a range of network operations.

Novell servers produce high levels of throughput because performance is one of the company's primary design goals for the NetWare architecture. Whereas OS/2 has been designed to coordinate diverse application processes in a preemptive environment, Novell's nonpreemptive architecture is optimized for high-performance file and print service.

Several techniques ensure the speed of NetWare processing, but file caching is one of the most important. NetWare servers support caches of 6MB or more. In addition to caching files, NetWare caches file allocation tables (FATs) and directory tables. In addition, the FAT index feature in NetWare 2.1 reduces time for operations on large files to a fraction of that required with nonindexed FATs.

NetWare's dual disk channels use a proprietary drive controller board with a disk coprocessor to manage disk accesses. This is part of NetWare's fault tolerant system that lets servers split disk seeks on mirrored drives so reads are performed from two drives independently.

NetWare's performance-enhancing features encourage high throughput. To determine the effect on DOS file operations, *PC Tech Journal* tested performance using its throughput measuring utility, LANPERF (introduced in "Network Complexity," this issue, p. 44). The test system comprised 8088, 80286, and 80386 workstations on a Token-Ring and a Compaq Deskpro 386/16 file server with 6MB of RAM. The NetWare 2.1 operating system on the 386/16 was configured with standard settings, such as 80 routing buffers and a maximum of 300 files open at once.

The first test series examined throughputs for a single station on the test network with no other network load. LANPERF generated traffic and measured throughput in kilobytes per second (KB/s). To obtain baseline readings, tests were run initially on the local hard drive of a 10-MHz AST Premium/286 with no network shell loaded. The block size and file size for test operations were varied by changing the command-line parameters for LANPERF. For overlaid compatibility mode reads, in which the block size was equal to the file size, the throughputs for the local drive read test were as follows:

BLOCK SIZE (bytes)	THROUGHPUT (KB/s)
1	1.37
10	13.56
64	84.12
256	302.74
512	478.30
1,024	59.70
2,048	119.50
4,096	119.60

The relatively high throughput associated with block sizes below 512 bytes is the result of DOS buffering. The throughput for a similar write test was 5- to 10-percent less than for reads, but also benefited greatly from local buffering.

The local drive test was also run with the NetWare shell loaded, and considerable performance degradation was observed during buffered operations. This is because each DOS operation is trapped by the shell, whether to a local or a network drive. Buffered operations to a local drive were 10- to 20-percent slower with the shell loaded.

The read test was run on the same station to a network drive with the following results:

BLOCK SIZE (bytes)	THROUGHPUT (KB/s)
1	2.73
10	26.84
64	162.26
256	534.78
512	64.20
1,024	97.40
2,048	98.50
4,096	96.60

The network throughput figures were higher than local test figures for buffered operations, but lower for larger blocks that must go to the server, due to network latency. The NetWare shell buffered blocks of 256 bytes or less. As a result, overlaid operations using 257-byte blocks went to the server. The buffering of the shell is optimized for typical network application file operations. Long sequential writes and reads produced throughput that was equal to, or slightly less than,

check during initialization that throws transaction tracking off. Novell provides a command-line utility called SETTTS to coordinate TTS with such database applications.

Only programs that are customized for NetWare can use explicit mode, which, as the name implies, is more precise about the bounds of database transactions. A program using explicit TTS begins a database access by making a "begin transaction" call to NetWare and ends it with an "end transaction" call. Thus, the operating system always knows the status of transactions.

Extended function calls. Support for DOS file operations and locking calls is only a portion of the functions available to programmers in the NetWare environment. The 150 or more NCP functions comprising NetWare's basic client-server interface are available to applications on any NetWare client station once the shell is loaded. The NCP functions provide services relating to security, enhanced file and directory maintenance, access rights, file-server usage, user accounts, billing, interstation messaging, printer and queue management, locks and semaphores for data access synchronization, and more.

NCP functions are executed as standard DOS calls with INT 21H, but use function values above the DOS range between B6H and F3H. The DOS file attributes are extended by NetWare also. For example, DOS function 3CH (create-file) uses an attribute byte to request the type of file to be created—read-only, hidden, or system. In the NetWare environment, function 3CH can be called with an extended attribute byte of 80H. When the call is trapped by the shell, it is interpreted as a request to create a file with the NetWare shareable attribute set. For existing files, the NetWare extended function call B6H can set the file attribute to shareable.

Application programming interfaces. In addition to the client-server interface available in the NCP functions, NetWare supports more than 20 distinct APIs. Those relating to file-server functions

overlaid operations when buffering was not a factor.

The mode with which a file is opened affects whether it is buffered locally. Files opened with exclusive modes that deny subsequent read or writes are buffered locally, but files opened as shareable (deny-none) require a trip to the server. File operations that are not buffered locally require at least one packet to the server and a return acknowledgment packet. For these operations, the server, workstation, and network link determine throughput. While the 10-MHz Premium/286 delivered a throughput of almost 100 KB/s in the above test, the Deskpro 386/16 running the same procedure reached 128.20 KB/s.

MULTIPLE STATIONS

Tests also were run for network configurations with multiple stations. LANPERF synchronizes testing so that all stations start and stop simultaneously. As many as 12 workstations were tested together, including machines such as the Deskpro 386/16, 8-MHz IBM PC/AT, IBM PS/2 Model 50, 10-MHz AST Premium/286, and 4.77-MHz IBM PC. The throughput figures reflected the presence of multiple machines sharing the network media and server. The Premium/286 that previously yielded 100 KB/s was reduced to 20.40 KB/s when the test was run by 12 stations.

A machine's speed or processor type had little effect on throughput during multistation tests. During a 10-station test of 8-MHz 80286 and 16-MHz 80386 machines, the average throughput was 24.30 KB/s and the mean deviation from this average was less than 0.1 KB/s. Whether 80286 or 80386, stations delivered virtually the same throughput under heavily loaded conditions. The 4.77-MHz PC was the only exception—it ran 10- to 20-percent slower than the 16- and 32-bit machines for all operations. Considering that throughput was affected considerably by processor speed in the single-station tests, the limiting factor for multiple-station tests had to be the server or the data link, not the station.

The aggregate server throughput was determined by adding the throughput for each station in a group test. The highest obtainable aggregate represents the maximum effective throughput for the server on a topology. Read tests with large block sizes (1KB, 2KB, 4KB) uniformly produced aggregate server throughput of 240 to 245 KB/s. Above a minimum number of stations, varying the number of stations changed the throughput for each station, but not the server's aggregate figure.

In the course of multiple-station testing, it was found that the throughput for each machine could be computed by dividing the number of stations under test into 240. For example, 12 stations delivered 20 KB/s each, 6 stations delivered 40 KB/s each, and so on. None of the multistation write tests saturated the network as the reads did, which can be attributed to disk latency. The highest level of aggregate server throughput for writes was approximately 210 KB/s.

Considering that the utilization on the server console never went higher than 75 percent during testing, it can be assumed that the 240-KB/s aggregate figure for the Token-Ring server approaches the effective limits of the test topology, not the server. Novell reports that similar tests on heavily loaded 80386 servers on a Token-Ring network have demonstrated an aggregate throughput as high as 270 KB/s.

Novell-conducted tests on Ethernet 80386 servers resulted in throughput of better than 660 KB/s. This corroborates the theory that the IBM Token-Ring boards and drivers are saturating before the 80386 server can deliver its maximum throughput. Because 6-MHz 80286 NetWare servers on Token-Ring reach 100-percent server utilization, the conclusion is that 386 servers running NetWare are capable of throughput higher than IBM Token-Ring boards and drivers can deliver. As verified by the test results, Token-Ring represents neither the fastest nor the slowest performance possible with NetWare.

In the tests conducted by *PC Tech Journal*, NetWare performed extremely well under both single- and multiple-station configurations. A single station on the network delivered throughput comparable to that of DOS operations on a fast local drive. The multiple-station network tests allocated the resources of the server equitably among machines across a wide range of configurations. As with any system, the performance of NetWare is affected substantially by factors such as local caching, network load, and topology. Developers need to consider these issues when optimizing performance of network application software.

—Steven S. King

include a database API using Softcraft's Btrieve as a record manager on the server; third-party applications running in NetWare servers are called value-added processes (VAP). A job-queuing API supports development of servers for batch jobs, shared printing, large compiles, and other tasks to be queued for NetWare servers of all kinds.

NetWare 2.1 enhances network resource monitoring and diagnostic functions of previous versions. A network management and diagnostic API allows programs to gather statistics from IPX/SPX, disk systems, TTS, login connection tables, and so on.

Manufacturers of disk drives and other storage devices can take advantage of the value-added disk driver (VADD) API. Drivers are developed, with the help of Novell, to be distributed with NetWare-compatible storage hardware. Users link the third-party drivers to the NetWare operating system when server software is generated.

The communications APIs supplied by Novell are extensive. Lower-level APIs support packet construction and are used for development of bridges, gateways, and specialized servers. High-level APIs allow programs to emulate IBM 3270, IBM 5250, or asynchronous terminals. A store-and-forward message API aids in development of wide area mail systems and other long-distance, data-transfer applications.

Communications APIs from Novell include: NETBIOS, IPX, SPX, IBM high-level language API (HLLAPI), IBM low-level API (LLAPI), IBM LU 6.2, NetWare Asynchronous Service Interface (NASI), and an IRMA-compatible 3270 gateway interface. The NASI API works with the NetWare Asynchronous Communications Server and is used to develop terminal-emulation, modem-sharing, and file-transfer applications.

Novell has gone to great lengths to open its APIs to programmers. More than 2,500 firms are registered in its Independent Software Vendor Program (ISV), which is free of charge. To qualify, vendors need only have a network product in the design or planning stages. Telephone support is free and documentation is available at a nominal fee. Registered ISVs can purchase NetWare products at 29 percent off list price from their local dealer or regional NetWare center.

A LONG LIFE

Novell's success in the LAN industry is a result of the quality of its network services and the speed with which it responds to the needs of the technical community. This is not to say that users have not sometimes waited for products, bug fixes, or updates from Novell, but relative to the industry as a whole, Novell consistently delivers improved services to DOS clients as fast or faster than other vendors.

Novell's real strength lies in its server-based file and print services, which deliver consistently high performance. The administrative functions that support these services are also well executed. The quality of these services make NetWare a viable solution for users with demanding database and document-processing applications. This viability has been increased by its system fault tolerant features.

The arrival of Microsoft LAN Manager and increasing industry competition will mean adversity for Novell in coming months.

The internetworking architecture of NetWare is well implemented, but its communications services need improvement. Specifically, the modem servers and wide area bridges need to be more tightly integrated. NetWare's resource access scheme is location-dependent and requires users to enter the physical path to a resource. Without a name service to facilitate network access, NetWare internetworking capabilities will not be fully exercised.

Improvements in name service and communications are not the only challenges in Novell's immediate future. The endorsement of Microsoft's LAN Manager by many large vendors presents perhaps the greatest challenge to Novell's current dominance of the LAN industry. Although Novell plans to interoperate with the LAN Manager environment, it is one of the few companies that has not announced it will license the product. Novell is taking OS/2 and LAN Manager very seriously and is in the process of porting NetWare to an OS/2 platform.

NetWare as a native operating system or running under OS/2 leaves Novell supporting Microsoft's architecture as an outsider, as it has with the redirector and MS NET. No one has been better at interacting with Microsoft system software than Novell, but emulating LAN Manager functions from the NetWare environment is significantly more involved than supporting DOS functions. It remains to be seen whether Novell can support OS/2 and LAN Manager clients as well as it supports DOS clients. This is a particularly important consideration for developers deciding which LAN APIs to write to.

One of Novell's strengths in the past has been accurately projecting user needs for LAN technology. Its intentions to support multiple-client operating systems, protocols, and hosts indicate that Novell is still anticipating the real needs of the end-user community. A recent Novell annual report states that the company has had to "navigate a sea of adversity" to reach its position of leadership in the LAN industry. The arrival of LAN Manager and increasing competition in the industry means there will plenty of adversity for Novell in coming months. But if past performance is any indicator, Novell will rise to the occasion, improving its services and continuing to add value to evolving LAN standards.

With its advanced file system and robust administrative services, Novell's NetWare 2.1 in many ways represents the state of the art for LAN operating systems. In evaluation and testing, this product exhibited a unique combination of ergonomics, sophistication, and dependability. Although its advantage may not last forever, Novell's basic client services are superior to competing products, and the LAN community is already hard at work learning the new features. NetWare 2.1 has the normal measure of compatibility problems and bugs that comes with any major operating system upgrade, but it is remarkable in the degree to which it meets user needs. Undoubtedly it will enjoy a long and useful life cycle.

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Provo, UT 84601
800/453-1267; 801/379-5900
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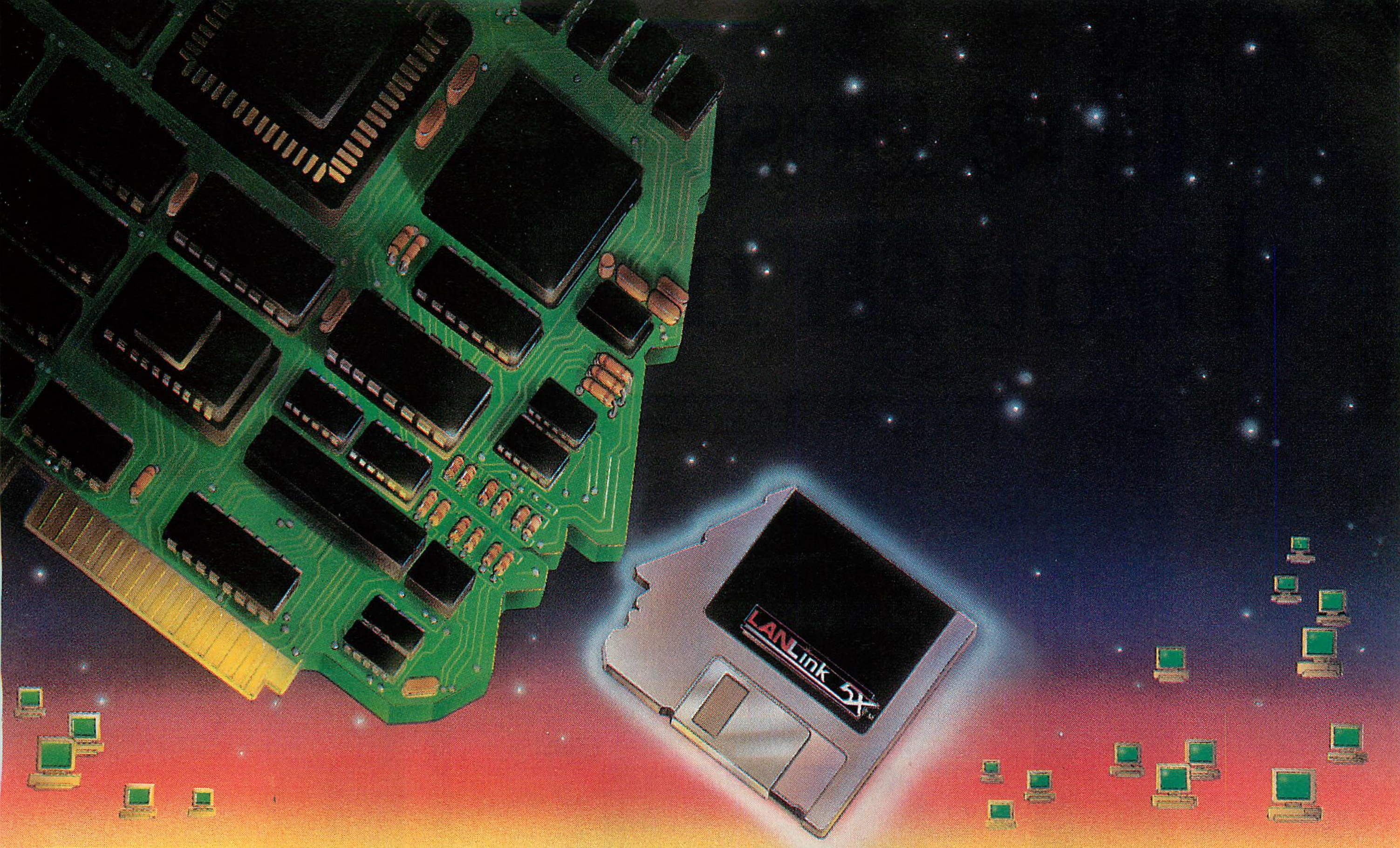
CIRCLE 348 ON READER SERVICE CARD

Steven S. King is a technical editor with PC Tech Journal, *specializing in networks.*



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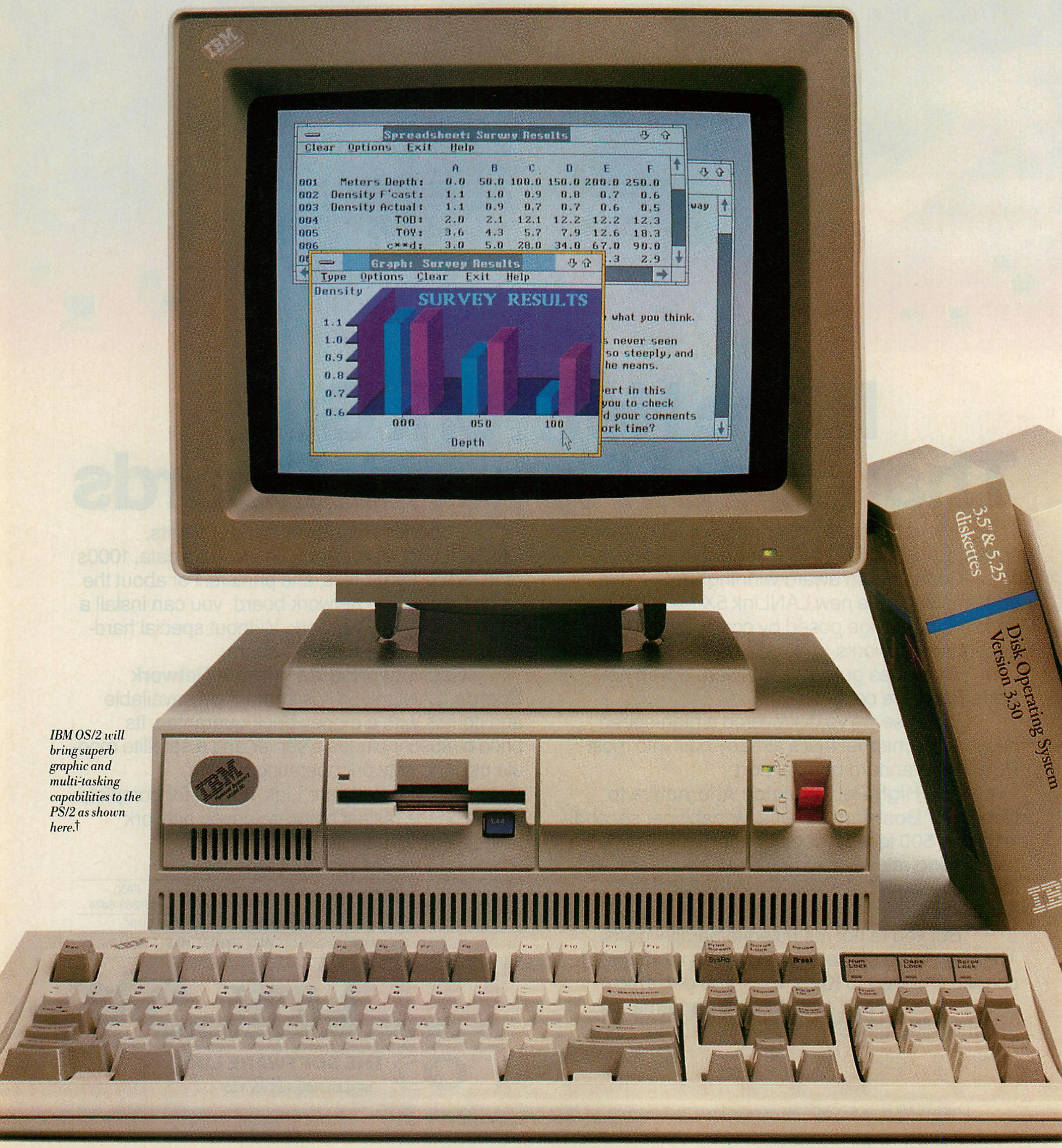

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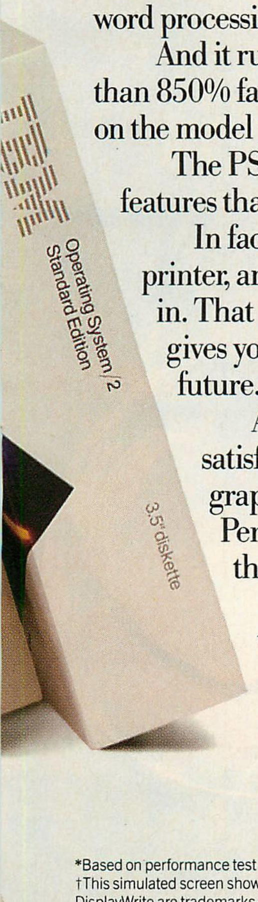

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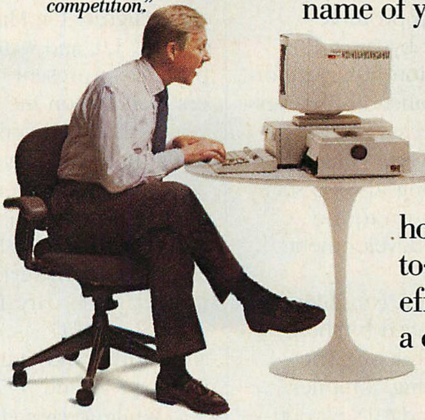

IBM The Bigger Picture

*Based on performance test results published in the April, 1987 and January, 1988 issues of *PC Digest*, comparing the PS/2 Models 30, 50, 60 and 80 to the IBM PC XT, running Lotus 1-2-3 and DisplayWrite 4.
†This simulated screen shown was developed using the IBM Storyboard Plus program. IBM, Personal System/2 and PS/2 are registered trademarks; PC XT, Operating System/2, OS/2, Micro Channel and DisplayWrite are trademarks of IBM Corporation. Lotus and 1-2-3 are registered trademarks of Lotus Development Corporation. © IBM 1988.

Highly Polished C Code

Aiming for faster and tighter programs, C compilers vary from mediocre to magnificent in how they optimize machine-level code.

PHILIP N. HISLEY

First, C vendors aimed for full compliance with the Kernighan and Ritchie standard, then it was faster compile times, followed by complete memory model support for the Intel 80x86 family of microprocessors, followed by attempts to promote source-code portability by providing UNIX-compatible function libraries, followed by specialized function libraries to provide low-level access to PC-specific features, followed by attempts to adhere to the evolving ANSI C standard, followed by a return to the womb with integrated development environments . . .

The latest trend in C compilers is *optimization*, as evidenced by these current claims from vendors: "The most powerful optimizing compiler ever!" (Turbo C, Borland); "New optimizations generate the fastest code!" (C 5.0, Microsoft); and, "Optimizer ruthlessly searches for ways to speed up execution and minimize memory usage!" (Optimum-C, Datalight). With this trend in mind, *PC Tech Journal* developed a benchmark to test code optimization capabilities of C compilers for the PC. This benchmark was run on nine compilers: Borland Turbo C 1.5, Computer Innovations C86Plus 1.10, Datalight Optimum-C 3.14, Lattice MS-DOS C 3.2, Manx Aztec C86 4.0, Metaware High C 1.4, Microsoft C 5.0 and QuickC 1.0, and WATCOM C 6.0. These products represent the best C compilers available on the PC. The tests revealed that each applies different optimization techniques with varying success. Other compilers are available, but their performance is generally below the ones examined here. Most of these compilers were reviewed in *PC Tech Journal*'s February 1988 cover suite, "The State of C" (see "C Contenders" and "Turbo and Quick Weigh In," Marty Franz, p. 52 and p. 72, respectively).

While today's C compilers offer similar capabilities, optimization is one important remaining difference that can be used to discriminate among them. The job of a language compiler is to translate a procedural description of a problem and efficiently map it onto the underlying machine-level instruction set

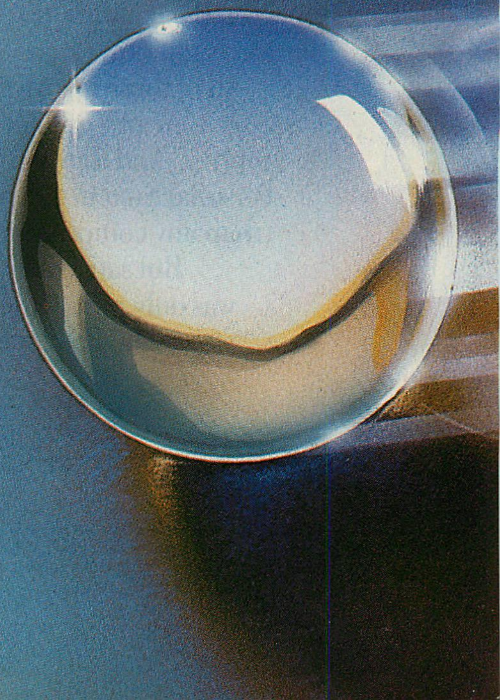

ILLUSTRATION • GREG FITZHUGH

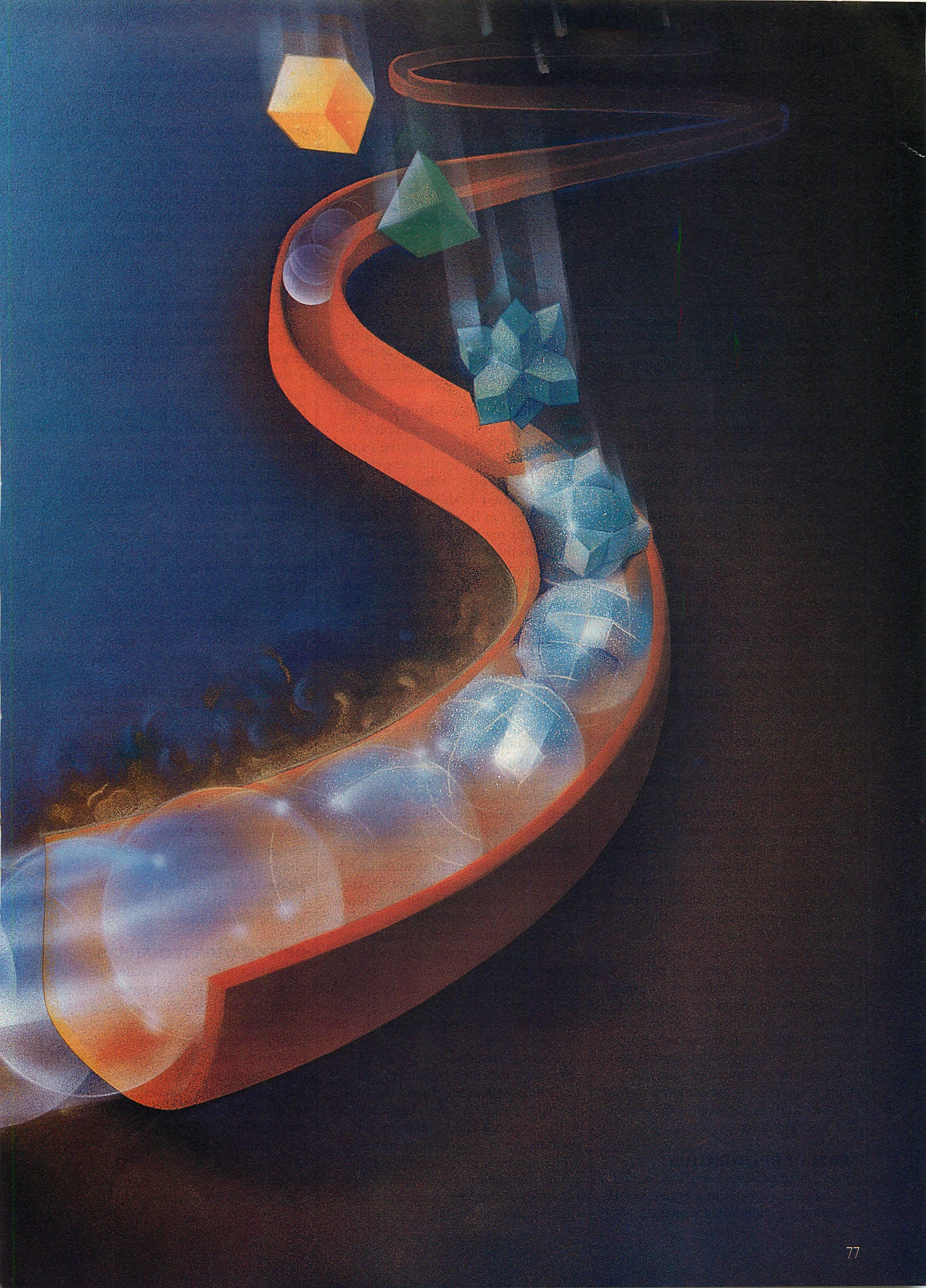

FIGURE 1: ***Common-Subexpression Elimination***

C SOURCE CODE

```
if(( h3 + k3 ) < 0 || ( h3 + k3 ) > 5 )
   printf("Common subexpression elimination\n");
```

BORLAND Turbo C 1.5

```
        mov     AX,h3
        add     AX,k3
        jl      @18
        mov     AX,h3
        add     AX,k3
        cmp     AX,5
        jle     @17
@18:    mov     AX,offset s@
        push    AX
        call    printf
        mov     SP,BP
@17:
```

LATTICE MS-DOS C 3.2

```
        mov     AX,h3
        add     AX,k3
        js      L0187
        cmp     AX,5
        jle     L0193
L0187:  mov     AX,01.0000
        push    AX
        call    printf
        add     SP,2
L0193:
```

Multiple occurrences of a calculation are replaced with a value that is the result of a single instance of the calculation. Borland Turbo C calculates the value of the redundant expression *h3 + k3* twice, while Lattice MS-DOS C and others apply common subexpression elimination and calculate the expression only once.

of the target processor. How effectively a compiler generates machine-level code can have a significant effect on how fast a program will execute and the size of the translated program.

The ultimate goal of code optimization is to produce faster and smaller code. In the mainframe environment, where the amount of available memory on a computer system is a limiting resource shared by multiple users, code space optimization is important. In the PC environment, *speed* optimizations have a higher priority because the PC generally is used by a single person, and large amounts of memory are affordable (most PCs have at least 640KB of RAM and many contain multiple megabytes of expanded or extended memory). The best evaluation of a C compiler's proficiency at optimizing code on the PC, therefore, concentrates on the compiler's speed.

Thorough, up-front analysis and clean program implementation provide a solid base for any later refinements that might be supplied by optimizing compilers. Code optimization cannot be expected to compensate for a program whose task structure is poorly organized or for the selection of an inappropriate processing algorithm. Current optimization technology, for example, does not intuitively substitute a quick-sort algorithm for a specified bubble sort, even though the former might produce a faster executing program. In addition, through careful code construction, programmers can easily effect some code optimizations, such as constant folding, invariant code motion, and loop jamming.

SCOPE OF OPTIMIZATION

The term *optimizing compiler* is used by compiler vendors in a general sense to define compilers that provide any level of optimization—from the most fundamental to the most complex. To distinguish between the degree of optimization provided by different compilers, a more precise definition of the term is needed. Code-optimization techniques can be applied at different levels with regard to syntactic range. From the most rudimentary level to the most complicated, they are: statement, block, loop, procedure, and program. The greater the range of optimization, the greater the opportunity for improving the overall efficiency of the program module. The trade-off for applying a greater degree of optimization, however, can be a significant increase in compile time.

The *statement* range is a single syntactic unit within a program. Most compilers perform some sort of optimization at this, the simplest, level.

A *block* is a sequence of statements for which a single entry point and a single exit point exist. The linear aspect of a block of instructions allows a compiler to perform optimizations based on the life span of variable data and expressions used within the block. An optimizing compiler determines the operational structure of a program by constructing a directed (or flow) graph of the program in which each node represents a basic block and connections between nodes represent the flow of control. Most compilers optimize at the block level.

A *loop* contains a sequence of statements executed repetitively. Because many programs spend the most processing time in loops, optimizations in this area can yield significant improvements in execution performance. While common in minicomputer and mainframe optimizing compilers, optimizations at the loop level are new for C compilers for the PC.

Procedures are statements contained within complete subroutines or functions. Optimizations over this range are not commonly performed by compilers for the PC.

The most complex range of optimization, the *program* level, is only a theoretical concern at this time and has not been introduced by any commonly available C compiler on PCs, minicomputers, or mainframes. Vendors who claim their compilers perform global optimizations are referring to the procedure level, not the program level.

Code optimizations can be dependent on, or independent of, a computer's underlying architecture. Compiling a computer program involves two basic functions: syntactic/semantic analysis (front-end) and code generation (back-end). Syntactic/semantic analysis depends heavily on grammar and is specific to a language; code generation is generic and ideally can be used to support front ends for any number of programming languages.

Source code for a particular language is first translated into a common intermediate form that is subsequently processed by code generation to produce machine-specific executable code. *Machine-independent* optimizations, such as common subexpression elimination and invariant code motion, are applied to this intermediate code. *Machine-dependent* optimizations apply to the output of code generation and take advantage of the instruction set of a particular processor. They are known as *peephole* optimizations because they operate over a small window (5 to 10 machine-level instructions).

Typical examples of peephole optimization include elimination of redundant load/store operations, dead-code elimination, jump-chain compression, algebraic simplification, strength reduction, and application of processor-specific instructions.

OPTIMIZATION TECHNIQUES

Several techniques for machine-dependent and machine-independent code optimizations exist; they can be applied over all of the syntactic ranges. *Constant propagation* is one of the simplest techniques. It replaces any reference to a constant value with the value itself. In the following statement, this improves efficiency by eliminating three address references and replacing them with constants:

```
x = 2;
  if( a < x && b < x )
    c = x;
```

FIGURE 2: *Simple Loop*

C SOURCE CODE

```
k5 = 10000;
j5 = 0;

do {
    k5 = k5 - 1;
j5 = j5 + 1;
i5 = ( k5 * 3 ) / ( j5 * constant5 );
} while ( k5 > 0 );
```

(x) = Clock cycles

BORLAND Turbo C 1.5

```
        mov   j5,0
        mov   k5,10000
@10:
        mov   AX,k5
        dec   AX
        mov   k5,AX
        mov   AX,j5
        inc   AX
        mov   j5,AX
        mov   AX,k5
        imul  AX,AX,3
        push  AX
        mov   AX,j5
        imul  AX,AX,5
        mov   BX,AX
        pop   AX
        cwd
        idiv  BX
        mov   i5,AX
        cmp   k5,0
        jg    @10
```

(125)

METAWARE High C 1.4

```
        mov   j5,0
        mov   k5,10000
L00e3:
        dec   k5
        inc   j5
        mov   AX,j5
        mov   SI,AX
        sal   SI,2
        add   SI,AX
        mov   AX,k5
        mov   DX,AX
        add   DX,DX
        add   DX,AX
        xchg  AX,DX
        cwd
        idiv  SI
        mov   i5,AX
        cmp   k5,0
        jnle  L00e3
```

(87)

MICROSOFT C 5.0

```
        mov   j5,10000
        mov   k5,0
        mov   CX,30000
        sub   SI,SI
$D265:
        sub   CX,3
        add   SI,5
        mov   AX,CX
        cwd
        idiv  SI
        mov   DI,AX
        or    CX,CX
        jg    $D265
        mov   i5,DI
```

(46)

WATCOM C 6.0

```
        mov   j5,0
        mov   DI,10000
L4      dec   DI
        imul  AX,DI,3
        inc   j5
        imul  BX,j5,5
        cwd
        idiv  BX
        mov   i5,AX
        test  DI,DI
        jg    L4
```

(91)

The Microsoft C 5.0 compiler performed strength reduction on the constant multiplies and enregistered all variables within the simple loop including the calculated value of *i5*. The high degree of loop analysis that was performed is indicated by the fact that the termination states of both *k5* and *j5* were determined earlier by the compiler and not later at runtime.

translates into

```
x = 2;
if( a < 2 && b < 2 )
    c = 2;
```

Closely related to constant propagation is *copy propagation*. It copies variables instead of constant values. For example,

```
x = y;
if( a < x && b < x )
    c = x;
```

translates into

```
x = y;
if( a < y && b < y )
    c = y;
```

Constant and copy propagation also can eliminate useless (dead) assignments ($x = 2$ or $x = y$ in the examples). Of the compilers reviewed, only Microsoft C 5.0 and WATCOM C 6.0 applied constant propagation.

The technique of *constant folding* (constant arithmetic) reduces expressions that contain constant data to the simplest form possible. Using constant data in a program is common, either directly (as in a number or digit) or indirectly (as in a declared manifest constant). Constant folding reduces the following statement:

```
#define TWO 2
a = 1 + TWO;
```

to its equivalent form,

```
a = 3;
```

at compile time, thereby eliminating unnecessary arithmetic operations at runtime. In C, constant folding applies equally to both integer constants and floating-point constants.

Algebraic simplification is a type of constant folding that eliminates arithmetic identities. Code generated for statements such as

```
x = y + 0;
x = y * 0;
x = y / 1.0;
x = y / 0;
```

should be simple assignments and should not contain instructions to perform arithmetic operations. An alert compiler should flag the last statement as an error and not generate code.

Common-subexpression elimination is the process of removing redundant computations. Rather than generating code to compute a value every time it is used, optimizing compilers attempt to isolate the computation so that its value is calculated only once. Where possible, subsequent references to the same computation use the previously calculated value. The expressions $y * 3$ and $a[y * 3]$ are the common subexpressions in the following:

```
if( a[ y * 3 ] < 0 || b[ y * 3 ] > 10 )
    a[ y * 3 ] = 0;
```

Eliminating these expressions results in the logical equivalent:

```
T1 = y * 3;
A1 = &a[ T1 ];
A2 = &b[ T1 ];
if( *A1 < 0 || *A2 > 10 )
    *A1 = 0;
```

Common-subexpression elimination usually takes place within a statement or block range; *Very busy expression elimination* is more complex and spans basic blocks. Eliminating the very busy expression, $y * 3$, in the statement

```
if( a==0 )
    a = y * 3;
else
    b = y * 3;
```

results in the logical equivalent:

```
T1 = y * 3;
if( a==0 )
    a = T1;
else
    b = T1;
```

Figure 1 shows the practical benefit of common-subexpression elimination in actual code.

Strength reduction involves replacing operations that require lengthy execution time with ones that are faster. A compiler can apply strength reduction in several ways. For example, a compiler applying strength reduction to its generated code might translate operations that multiply or divide integers by a power of 2 into shift operations.

Dead-code elimination is another optimization technique. Dead code is any sequence of instructions in a program that cannot be reached by any path through the program. It can result from previous optimizations, from conditional debugging code inserted into programs, or from frequent modifications by multiple programmers. The following statements are candidates for dead-code classification:

```
#define DEBUG 0
if( DEBUG )
    printf( "Debug Function\n" );
```

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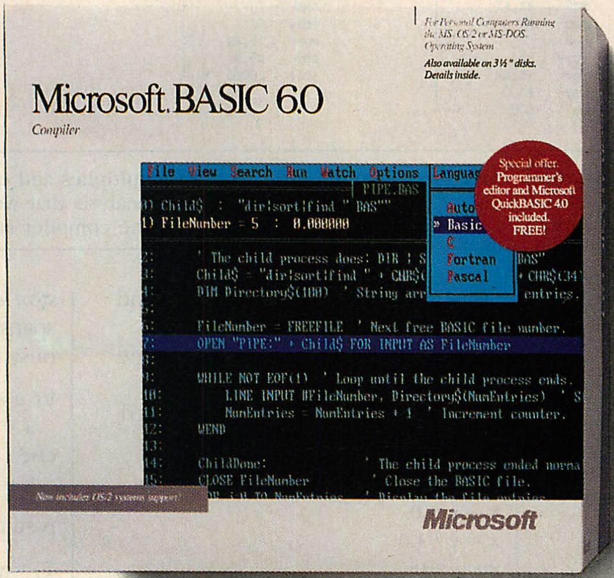

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FIGURE 3: *Invariant-Code Motion—Microsoft C 5.0*

C SOURCE CODE

```
for( i4 = 0; i4 <= 2; i4++ )
   ivector2[ i4 ] = j * k;
```

MICROSOFT C 5.0

```
          sub    SI,SI
          mov    AX,j
          imul   k
          mov    [BP-4],AL
$L20007:
          mov    AL,[BP-4]
          mov    ivector2[SI],AL
          inc    SI
          cmp    SI,2
          jle    $L20007
          mov    i4,SI
```

COMPUTER INNOVATIONS C86Plus 1.10

```
          mov    i4,0
          jmp    L44@2
L9@2:
          mov    AX,j
          imul   k
          mov    SI,i4
          mov    ivector2[SI],AL
          inc    i4
L44@2:
          cmp    i4,2
          jle    L9@2
```

Invariant code motion reduces loop execution time by moving nonvarying expressions out of the body of the loop. Unlike Computer Innovations C86Plus 1.10, Microsoft C 5.0 successfully moves the expression $j * k$ out of the loop so that it is executed only once, instead of being executed on each iteration of the loop.

FIGURE 4: *Loop-Induction-Variable Elimination*

C SOURCE CODE

```
for( i = 0; i < 100; i++)
     ivector5[ i * 2 + 3 ] = 5;
```

MICROSOFT C 5.0

```
          mov    i,100
          mov    SI,OFFSET ivector5+6
$L20006:
          mov    [SI],5
          add    SI,4
          cmp    SI,OFFSET ivector5+406
          jb     $L20006
```

DATALIGHT Optimum-C 3.14

```
          mov    AX,0
          mov    i,AX
          cmp    AX,100
          jge    L134
L11B:     mov    BX,i
          shl    BX,1
          shl    BX,1
          mov    ivector+6[BX],5
          inc    i
          cmp    i,100
          jl     L11B
L134:
```

Loop-induction-variable elimination helps to minimize the time spent in each iteration of a loop by removing loop-index variables (induction variables) from the body of the loop. While Datalight Optimum-C uses the induction variable i to index into the array *ivector5*, Microsoft C 5.0 eliminates it by accumulating the offset for each array entry and adding the result to the base address of the array.

Manifest constants often can mask the existence of dead code, particularly if such code is embedded within included header files.

Dead-store elimination involves determining the life span of a variable and eliminating assignments to that variable if those assignments have nothing to do with the program's logic. It frees limited resources such as stack space or a machine register. In the following instruction sequence:

```
a = 5;
b = 0;
a = b;
```

the first statement is a dead store and can be eliminated safely. Dead stores can occur inadvertently when the life of a variable is long and code is somewhat lengthy between instances of the variable. Dead stores also can result from a previous optimization pass.

The goal of *enregistering* is to attempt to provide optimal register assignment by keeping frequently used variables in registers as long as possible to eliminate slower memory accesses. The number of registers available for allocation depends on the architecture of a processor. The Intel 80*x*86 family reserves many registers for specific use and has few general-purpose ones. To assist enregistering, the C language provides a *register storage class specifier* that allows a programmer to suggest which variables should be placed in registers.

When enregistering variables, a compiler considers not only which variables to allocate, but also the registers to which they are assigned. Allocation of variables depends on the frequency of variable use, the life span of currently enregistered variables (as determined by data flow analysis), and the number of available registers. Depending on the degree of optimization performed by a compiler, the life span of a variable could be within a single statement, within a basic block, or over several basic blocks. A variable is kept in a register only if it will be used again. When the variable is not subsequently referenced, it is stored in RAM, freeing the register for another variable.

Because the optimizing compiler knows the life of a variable, it should not intentionally generate *redundant store* or *load operations*. Redundant store operations are deleted through dead-store elimination; redundant load operations are omitted through better enregistering. Using the following:

```
a = i + 2;
b = a + 3;
```

a nonoptimizing compiler might generate the following code:

```
mov   AX,i
add   AX,i
mov   a,AX
mov   AX,a
add   AX,3
mov   b,AX
```

while an optimizing compiler could use enregistering to eliminate the redundant fourth instruction (mov AX,a).

Time spent in loops can account for a major part of the total execution time of the program. Most important in loop optimization is minimizing the number of clock cycles required for one iteration of the loop. The number of instructions generated for the loop is not as significant as the number of clock cycles each instruction takes to execute. A simple loop and the code generated by four of the compilers show great variation in code size and quality (see figure 2).

Invariant-code motion is one way to speed loops by moving expressions outside of the loop if the values they calculate are constant throughout execution of the loop. If invariant code is optimized out of the following loop:

```
unsigned char i, j, k, v, x;
for( i = 0; i < v; i++ )
   x = i * ( j + k );
```

its logical equivalent would be:

```
T1 = j + k;
for( i = 0; i < v; i++ )
   x = i * T1;
```

Figure 3 demonstrates invariant code motion by Microsoft C 5.0. Further analysis of the invariant-code motion example shows that the value of i, the loop-index variable, varies directly with each iteration. The discrete assignment to i, known as the *loop-induction variable*, can be eliminated:

```
T1 = j + k;
for( x = 0; x < T1 * v; x += T1 );
i = v
```

Because use of loop-index variables in inner loop expressions is common, eliminating loop-induction variables,

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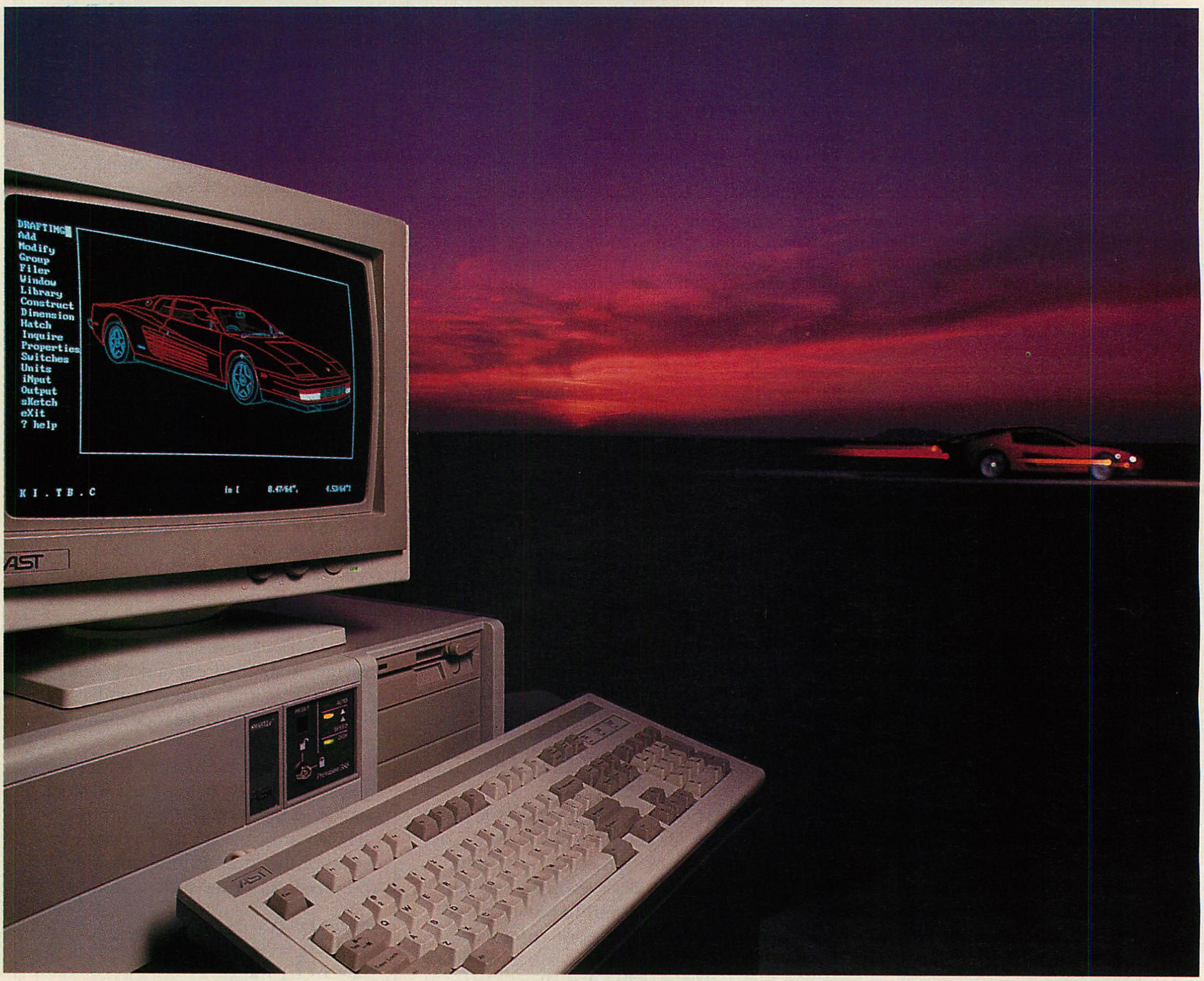

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along with associated strength reductions, can greatly improve performance. Figure 4 shows an example of loop-induction variable elimination.

Loop jamming minimizes loop-control overhead by coalescing code from loops sharing the same loop-control constraints into a single loop. To eliminate control overhead of a second loop, the two simple loops

```
for( i = 0; i < 10; i++ )
  a = b + c;
for( i = 0; i < 10; i++ )
  d = e + f;
```

could be united into the single loop

```
for( i = 0; i < 10; i++ ){
  a = b + c;
  d = e + f;
}
```

Because procedural optimization is required to support loop jamming, it generally is not performed. No compiler reviewed performs loop jamming.

Closely associated with loop jamming is *loop unrolling*, which minimizes the number of passes through a loop by increasing the number of operations performed within each iteration. The array-initialization loop

```
int a[ 3 ];
int i;
for( i = 0; i < 3; i++ )
  a[ i ] = 0;
```

translated by a nonoptimizing compiler, might generate the following assembly-language equivalent:

```
        mov   i,0
LOOP:
        mov   BX,i
        shl   BX,1
        mov   a[BX],0
        inc   i
        cmp   i,3
        jl    LOOP
```

The same code optimized by loop unrolling eliminates the loop by replacing it with three assignment instructions:

```
mov   a,0
mov   a + 2,0
mov   a + 4,0
```

Although none of the reviewed compilers performs literal loop unrolling, a few optimized the loop by using *processor-specific instructions*. Many processors provide specialized instructions to handle block data movement, memory initialization, and other frequent data-handling situations. For example, string instructions with a repetition prefix (on the 80*x*86 family of microprocessors), execute faster than literal instructions in a loop. When possible, an optimizing compiler should use the processor's underlying instruction to handle special-case situations. Applying processor-specific instructions to an extended version of the previous loop unrolling example:

```
int a[ 10000 ];
int i;
for( i = 0; i < 10000; i++ )
  a[ i ] = 0;
```

produces the following 80*x*86 assembly code. This is much faster than either a loop solution or a lengthy equivalent set of in-line store instructions:

```
mov    CX,10000
mov    i,CX
sub    AX,AX
mov    DI,offset a
push   DS
pop    ES
cld
rep
stosw
```

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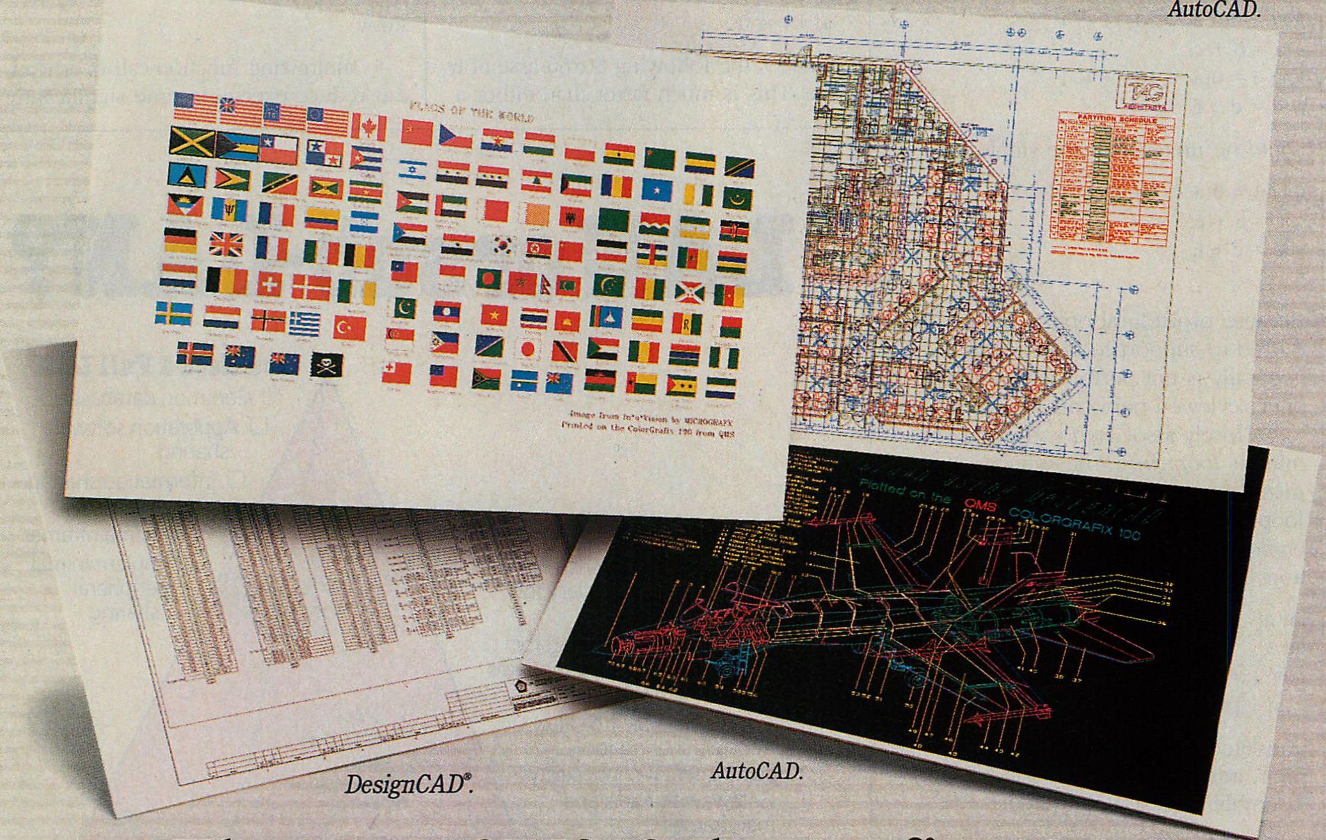

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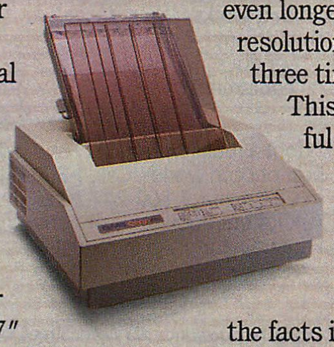

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FIGURE 5: ***Anatomy of Function-Call Overhead***

C SOURCE CODE

```
int funcall()   /* function calling benchmark */
{
    int i ;

    for( i=0 ; i < 20000 ; i=i+1 )
        { dummy(i) ; } ;
}

int dummy(i)
int i;
{
    return( i+1 ) ;
}

(x) = Clock cycles
```

MICROSOFT C 5.0

```
funcall     push    BP
            mov     BP,SP
            sub     SP,2
            push    SI
            sub     SI,SI
$l20008:    push    SI          <--
            call    dummy          |
            add     SP,2           |
            inc     SI             |-(31)
            cmp     SI,20000       |
            jl      $L20008     <--
            mov     [BP-2],SI
            pop     SI
            leave
            ret

dummy       push    BP          <--
            mov     BP,SP          |
            mov     AX,[BP+4]      |-(28)
            inc     AX             |
            leave                  |
            ret                 <--
```

WATCOM C 6.0

```
funcall     push    DX
            xor     DX,DX
L4          mov     AX,DX
            call    dummy       <--
            inc     DX             |-(23)
            cmp     DX,2000        |
            jl      L4          <--
            pop     DX
            ret

dummy       inc     AX          <--|-(13)
            ret                 <--
```

Like most C compilers, Microsoft C 5.0 passes parameters to functions by pushing them on the stack. Each time a function is called, overhead is incurred because the function must establish addressability to the stack-based parameters. However, the WATCOM C 6.0 compiler eliminates stack overhead by passing as many function parameters as possible in registers.

in a structured program. When a function call is performed, parameters are passed to the called routine on a RAM-based stack. Instruction sets of some processors contain instructions that support C and other structured high-level languages by establishing addressability to the stack frame before entering the function code and pruning the stack frame upon exiting.

Starting with the Intel 80186, the 80*x*86 family of microprocessors provide ENTER and LEAVE instructions to aid function-call processing. Usefulness of the ENTER instruction is diminished because it is much more costly in processor cycles than pushing the base pointer, moving the stack pointer to the base pointer, and subtracting the bytes to be allocated to the frame from the stack pointer.

An alternative to using a stack to pass parameters to a function is to establish a well-defined protocol and pass as many parameters as possible in registers. If enough registers are available to handle all function parameters and the called function uses no local variables, then the code for the function prologue and epilogue (usually required to establish stack-frame addressability) need not be generated. WATCOM C 6.0 uses this approach (see figure 5). A significant increase in speed is achieved because not only are instructions eliminated, but parameters already are enregistered and can be operated upon more efficiently.

Most C compilers permit developers to specify which processor instruction set to use in code generation. Although processor-specific instructions can speed program execution, using them may limit the number of machines on which a program can run.

For speed-critical situations, *in-line expansion of functions* can help eliminate function-call overhead. Some compilers provide a set of commonly used intrinsic functions, such as **abs**, to replace statements that would otherwise generate function calls. This optimization is useful for inner loops that execute many times. Available intrinsic functions are compiler-dependent.

A compiler that generates native code for a math coprocessor speeds code that performs many floating-point operations. To support a math coprocessor and maximize floating-point efficiency, an optimizing compiler should generate in-line sequences of native coprocessor instructions, as opposed to using a software emulation of floating-point functions.

When translating conditional instructions, compiler code generators occasionally generate jump instructions that transfer control to other jump instructions. In optimizing compilers, *jump-chain compression* simply changes linked sets of jumps into a single jump from the origin of the jump chain to the final destination.

TO OPTIMIZE OR NOT?

Optimization is not a panacea, nor is its application without cost. Depending on the degree of optimization, the time required to compile a program might be greatly increased. For smaller programs, the time required might not be noticeable, but for larger applications, it might be considerable.

Optimization also can complicate program debugging by generating code that is difficult to associate directly with source statements in the program. It inadvertently can introduce errors into code generated from perfectly legitimate program source code. Variable aliasing, in which a variable is referenced both directly and through one or two pointers, can make it difficult for a compiler to determine whether a variable is alive and therefore must be maintained, or whether it is dead and then can be stored.

Invariant code motion can be a potential source of errors. In the loop,

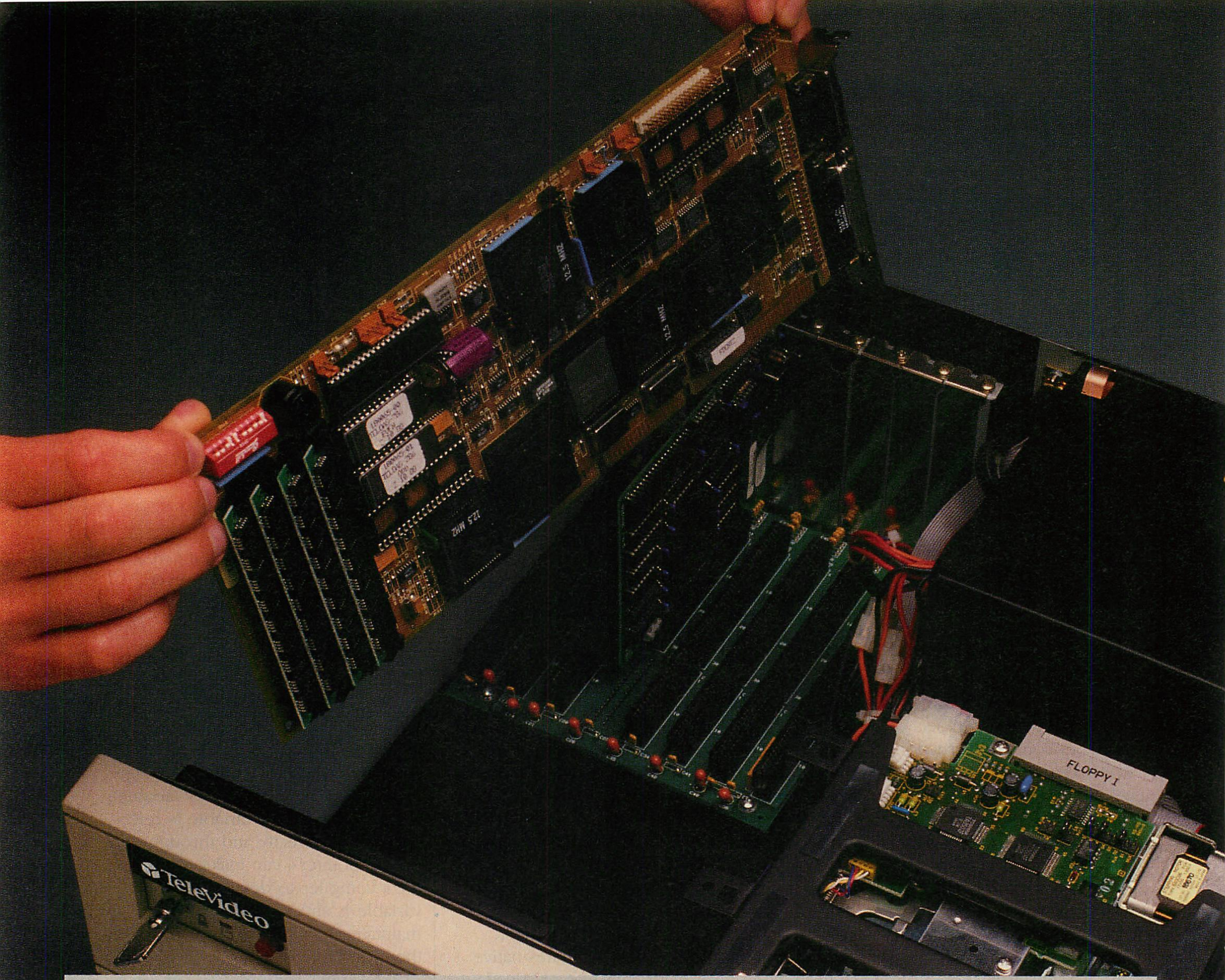
```
int a[ 10 ], x, y;
for( i = 0; i < 10; i++ )
  if( y != 0 )
    a[ i ] = x / y;
```

an optimizing compiler might determine that the expression $x\ /\ y$ is invariant and hoist it out of the loop, negating the check for a 0 value, and creating a possible divide-by-0 situation.

When a compiler performs loop-induction optimizations, it unintentionally can cause overflow situations because it can restructure calculations involving loop indexes. In the earlier example that optimized using invariant-code motion and loop-induction variable elimination, the induction variable *i* was removed, resulting in:

$$T_1 = j + k;$$
$$\text{for}(\ x = 0;\ x < T_1 * v;\ x += T_1\ );$$

In this case, because the values of j, k, and v are not known, a possible overflow condition exists for the expression $T_1 * v$; the loop might not terminate.



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INTRODUCING A BENCHMARK

PC Tech Journal has developed a C optimization benchmark (see listing 1) to help evaluate optimization capabilities of C compilers. The benchmark checks the degree of optimization performed by a compiler. To provide a comparative basis for performance measurements, *PC Tech Journal* C performance benchmarks were run for each compiler with optimization enabled; the results for each compiler are summarized in table 1. Figure 6 shows the optimization options used with each compiler for both benchmarks. Performances can be compared with nonoptimized measurements reported in the February 1988 cover suite (see p. 62 and p. 80).

For both the performance and the optimization benchmarks, the goal was to find the fastest possible code that could be generated by each compiler. Where a compiler provided options for code generation, they were chosen to favor time over space improvement, generate 80286 and in-line 80*x*87 instructions, and disable stack overflow checks. Thus, the minimum system required to run the benchmarks as compiled is an 80286 machine with an 80287 math coprocessor.

Many of the compilers also have options to generate code for an 80186 or NEC V20/V30 processor, which could be used for XT-class machines (see "Chips in Transition," Bob Smith, April 1986, p. 56). These processors share most features of the 80286 except for protected-mode instructions, so the code generated for them is typically the same as for the 80286.

Results of the performance benchmarks are summarized in table 1 for each compiler in the small and large memory models. Tests in the performance benchmark suite were arranged into functions that were called from a main driver routine. The entire suite was compiled and linked into a single .EXE file. Some of the benchmark routines execute so quickly that a single call to the benchmark function could not be measured accurately; in those cases, the function is called multiple times from the driver routine to increase the runtime to a measurable quantity. Iteration counts used for each test are shown in table 1.

FIGURE 6: *Command Lines*

BORLAND TURBO C 1.5

```
: tcc -1 -f87 -N- -S -O -G -Z -r optbench.c
```

COMPUTER INNOVATIONS C86PLUS 1.10

```
: cc -DNO_ZERO_DIVIDE=1 -c -FPi87 -Oatx
     -G2 -Fa optbench.c
```

DATALIGHT OPTIMUM-C 3.14

```
: dlc1 optbench.c  -f -g
  dlg optbench.tmp +vbe +all
  dlc2 optbench.tmo
```

LATTICE MS-DOS C 3.2

```
: lc -d -k2 -f -v optbench.c
```

MANX AZTEC C86 4.0

```
: cc -A +A -B -T +F +2 +ef  optbench.c
```

METAWARE HIGH C 1.4

```
: hc  optbench.c -def NO_ZERO_DIVIDE=1
  pragma Off(Check_stack, Check_subscript)
  pragma On(286, asm, auto_reg_alloc)
  pragma On(floating_point, optimize_xjmp)
  pragma On(optimize_xjmp_space, use_reg_vars
```

MICROSOFT C 5.0

```
: cl -DNO_ZERO_DIVIDE=1 -c -G2 -Fc
     -Ox optbench.c
```

MICROSOFT QUICKC 1.0

```
: qcl -c -G2 -FPi87  -Ox d:\optbench.c
```

WATCOM C 6.0

```
: wcc d:\optbench.c /d1 /oilt /s /2 /7
```

Executable code for the optimization and performance benchmarks that were used in this article was generated with the compiler directives contained in these command lines.

One correction should be noted when comparing the results in table 1 to those in the February 1988 issue. The two tests using register variables (pointer use and sieve) were given in February for 100 iterations rather than 20. Since a direct comparison of the test with and without the use of register variables is useful, the register variable tests are run for 20 iterations in table 1. Also note that the numeric tests that appear in table 1 were performed for in-line 80*x*87 code in both small and large models, rather than compiling and linking with an 80*x*87-sensing emulator library.

Because the optimization benchmark code is intended to verify the presence or absence of particular types of optimizations, it consists of a number of discrete, disassociated code fragments rather than a coherent problem-oriented code body. The benchmark is structured as a main function, containing most optimization code fragments and several separate functions, with and without arguments. These functions illustrate not only specific optimizations, but also the function prologue and epilogue optimizations that are performed. In order to provide a maximum opportunity for optimization predicated on the life span of a particular variable, most benchmark variables are global. Many opportunities have been provided specifically for common optimizations such as dead-store elimination, constant propagation, and variable enregistering.

The process of optimizing code is complex, and the degree of performance improvement depends not only on the type and sophistication of a compiler's optimization techniques but also on how a program's source code is written and structured. Performance also depends on how variables and expressions are used within it.

Table 2 summarizes the optimizations performed by each compiler on the benchmark code. Each compiler reviewed performed the most rudimentary forms of optimization, such as constant folding and algebraic simplification. Most performed some intermediate level of optimization, including strength reduction and common-subexpression elimination. A few performed high-level optimizations, such as invariant-code motion and the elimination of loop-induction variables. None successfully performed loop jamming, and only Datalight Optimum-C made a heroic, but futile, effort at very busy expression elimination.

Borland International. The output from the Turbo C compiler reveals reasonable but not highly optimized code. Besides constant folding, elimination of redundant loads, and algebraic simplification, the compiler performed only strength reduction, dead-code elimination, and enregistering. It did not support other common forms of optimization, such as elimination of dead stores, common subexpressions, and loop-induction variables, as well as invariant-code motion.

Turbo C enregistered variables and handled function prologues and epilogues intelligently, pushing and popping only those registers explicitly used within the body of a function.

Computer Innovations Inc. The C86Plus compiler produced good code with an intermediate level of optimization. It performed basic optimizations, such as constant folding and copy propagation; however, it did not propagate constants to eliminate dead stores.

Although successfully performing algebraic simplification, the compiler incurred unnecessary overhead by placing results in registers instead of as-

signing them to their variables. This appears to have been a misplaced attempt at enregistering because within a few statements, the results actually had to be assigned to their variables.

The C86Plus compiler's dead-store elimination, although successful in reducing duplicate in-line assignment instructions to a single assignment, was inconsistent. The single dead store in the **dead_code** function was the only instruction remaining after the compiler had eliminated dead code from the function.

C86Plus is one of the few compilers reviewed that transformed the simple array assignment in the loop unrolling function to an equivalent 80*x*86 STOSW instruction with a REP prefix. For its reasonable level of optimization in other areas, however, the compiler failed to resolve the jump chain in the **jump_chain_compression** function to a single jump. It performed no significant loop optimizations.

Datalight Inc. With Optimum-C, Datalight became one of the first vendors to advertise an optimizing compiler. Although the benchmark suite does not explicitly verify Datalight's claim of global optimization, Optimum-C performed so well in some areas of the benchmark suite that it illuminated weak areas of the suite, requiring modifications to force the desired test. For example, in the first version of the **jump_compression** function, no value was returned, making all calculations and assignments within the function dead. Optimum-C detected this condition and optimized out most of the code in the function, including the jump chain.

In the test for constant and copy propagation, Optimum-C determined that the assignments to *i5* in both conditionals were dead due to a subsequent assignment; the compiler optimized out not only the assignments but also conditional statements.

Dead-store elimination was inconsistent. Optimum-C eliminated one dead assignment, $i = k5$, in the constant and copy propagation test and the dead assignment in the **dead_code** function. It did not eliminate a second dead assignment, $i = 2$, in the constant and copy propagation test or $k3 = 1$, the duplicate in-line assignment.

Optimum-C is the only compiler that attempted very busy expression optimization. An examination of the generated code indicates that the common expression, $i5 + i2$, was hoisted out of the first basic block of the conditional but not out of the second.

TABLE 1: ***Optimized Performance Benchmark Summary***

	BORLAND	COMPUTER INNOVATIONS	DATALIGHT
COMPILER	Turbo C	C86Plus	Optimum-C
VERSION	1.5	1.10	3.14
PRICE	$99.95	$497	$139
PROGRAM SIZE (KB)	35/40	30/38	33/40
GENERAL OPERATIONS [a]			
Function calls (Fibonacci)	6.0/7.2	7.6/8.2	6.0/7.6
Integer arithmetic	7.0/7.0	8.5/8.5	6.3/6.3
Long arithmetic	29.0/29.0	23.4/23.9	26.3/26.9
Subscripts	7.9/9.9	7.9/11.4	5.9/7.9
Pointer use	6.2/15.3	12.9/19.2	6.8/15.3
With register variables	6.8/15.2	10.3/19.8	6.8/15.3
Sieve	5.0/5.0	5.8/5.8	4.3/3.8
With register variables	6.4/6.5	4.6/4.6	4.3/3.8
FILE OPERATIONS			
Read and write [b]			
Diskette to diskette	8.2/8.2	8.3/8.3	8.3/8.2
Hard disk to hard disk	3.9/3.4	3.9/3.9	3.9/3.3
Getc and putc [c]			
Diskette to diskette	49.8/50.6	45.6/50.1	**13.5**/49.4
Hard disk to hard disk	17.6/18.4	18.9/21.1	**5.5**/17.3
80*x*87 OPERATIONS			
Add/multiply (dot product) [a]	3.1/3.1	2.8/2.8	3.1/3.1
Exponential logarithmic [d]	1.0/1.0	1.3/1.3	1.3/1.2
Sin/tan (trigonometric functions) [d]	1.1/1.1	1.5/1.5	1.2/1.3

All times are in seconds, shown for small/large memory model.
Tests were performed on a 6-MHz IBM PC/AT with an 80287, with FILES = 20 and BUFFERS = 20 in CONFIG.SYS.
Values within 10 percent of the best for each test are shown in boldface.
[a] 20 iterations. [b] 1 iteration. [c] 2 iterations. [d] 10 iterations.

Beyond the standard usage constraints imposed by the 80*x*86 family, Optimum-C used registers intelligently. In the **jump_compression** function, every passed parameter was assigned to a register; except for the initial enregistering, no memory references existed within the body of the function.

The one important area in which the Optimum-C compiler needs improvement is loop optimization. The compiler did not attempt invariant-code motion, and it did not eliminate loop-induction variables.

The performance benchmarks show that Datalight's compiler handles **getc/putc** I/O very efficiently, and it turns in respectable times for the remainder of the tests.

Lattice Inc. The venerable Lattice MS-DOS C compiler has been enhanced incrementally with each release. Although known for generating stable, predictable code, it performed only a modest level of optimization. In addition to handling constant folding, algebraic simplification, and other basic optimizations, Lattice C performed strength reduction, jump-chain compression, and common subexpression elimination. It eliminates neither the duplicate in-line dead store after the intrinsic function test nor the dead assignment in the **dead_code** function. Although it did not generate any code for the dead **printf** statement in the **dead_code** function, the Lattice compiler generated an unnecessary unconditional jump to LEAVE, which is the next instruction.

The only machine-specific instructions generated were 80*x*86 ENTER and LEAVE for function prologues and epilogues. This was a mixed blessing because ENTER takes more clock cycles than does establishing stack-frame addressability with discrete instructions. It performed no loop optimizations.

Manx Software Systems Inc. The Aztec C86 compiler generated good code with a respectable level of optimization. Beyond constant folding and algebraic simplification, Aztec C86 performed strength reduction and common-subexpression elimination. It did not, however, handle dead stores or eliminate dead code. Aztec C86 obligingly generated code for the dead **printf** statement along with an unconditional jump around it.

LATTICE	MANX	METAWARE	MICROSOFT		WATCOM
MS-DOS C	Aztec C	High C	C	QuickC	WATCOM C
3.2	4.0	1.4	5.0	1.0	6.0
$500	$499	$595	$450	$99	$295
34/41	20/24	33/44	28/39	31/44	25/30
7.5/8.1	7.9/8.6	6.9/9.5	6.1/6.0	6.5/7.5	**3.8/4.5**
7.7/7.7	9.1/9.2	5.8/5.8	5.3/5.2	6.8/6.8	**3.7/3.8**
23.3/24.3	23.9/24.2	27.8/29.1	23.9/24.8	27.8/28.7	**20.0/21.0**
11.0/34.9	9.0/10.5	7.1/7.8	**4.8**/7.2	7.9/11.3	5.4/**5.5**
12.3/58.5	12.8/15.3	5.4/15.3	**5.1**/9.8	7.8/17.8	6.1/**6.2**
12.8/58.6	7.8/15.3	**5.2**/15.3	**5.1**/9.8	7.7/17.8	5.6/**6.2**
7.1/6.9	7.6/7.6	5.4/5.6	4.2/4.3	5.3/5.4	**3.2/3.4**
6.9/7.0	5.9/6.1	5.8/6.0	4.2/4.3	6.5/6.5	**3.2/3.4**
8.2/8.2	8.3/8.2	8.0/8.0	8.3/8.2	8.2/8.3	8.2/8.2
3.9/3.7	3.9/2.8	**1.0/0.9**	3.3/3.8	3.9/3.4	3.4/3.4
51.3/51.5	28.6/**27.7**	39.8/39.8	40.0/40.0	40.0/40.0	51.2/51.3
21.0/26.0	12.5/**11.0**	16.0/15.2	14.8/15.7	16.1/16.0	19.2/20.1
4.7/4.7	2.6/2.6	2.6/2.1	**1.7/1.7**	3.1/3.0	1.8/1.8
1.3/1.3	1.1/1.1	1.1/1.2	1.0/1.0	1.2/1.3	**0.9/0.9**
1.9/1.9	1.3/1.3	1.1/1.2	1.1/1.1	1.3/1.4	**1.0/1.0**

Compilers were set to optimize for speed and to use 80286 and in-line 80287 code. All the CPU-intensive tests were won by WATCOM and Microsoft. No compiler had consistently good times for the I/O tests in large and small models.

Because any C program will make a significant number of function calls, the overhead of each function call should be minimized. Aztec C86 takes an unorthodox but effective approach to this problem. The compiler creates assembly language output that it runs through a separate assembler. In the output, it inserts conditional assembly directives around the code to set up the stack frame and save registers. After generating code for a function, the compiler defines symbols to control stack frame setup and save only those registers used in the function.

Aztec C86 failed to resolve the jump chain into a single jump to the final destination, and it performed no loop optimizations.

Metaware Inc. High C produced good code with an intermediate level of optimization. The compiler performed all basic optimizations, including constant folding and algebraic simplification along with redundant-load suppression, strength reduction, and common-subexpression elimination. Metaware's compiler eliminated the dead code from the **dead_code** function but not the dead store.

High C made intelligent use of machine-specific instructions. The compiler facilitated floating-point constant loading by using the 80*x*86 string move instruction, MOVS, to store the floating-point value computed at compile time. It also generated an 80*x*86 LEAVE instruction for function prologues, but established stack-frame addressability in function prologues by generating discrete instructions rather than the more time-expensive 80*x*86 ENTER instruction.

The High C compiler did not perform invariant-code motion, an important loop-optimization technique, nor did it successfully apply induction variable elimination. Intrinsic functions are supported for a few numeric and string operations such as **strlen**.

Microsoft C. In version 5.0 of its C compiler, Microsoft Corporation brings a high level of code optimization to the PC marketplace.

Microsoft pays much attention to loop analysis. C 5.0 is the only compiler reviewed here that performed invariant-code motion and true loop-induction-variable elimination. The Microsoft C 5.0 compiler made excellent use of registers, attempting to minimize memory accesses within the body of loops (see figures 4 and 5).

The simple loop example in the benchmark code illustrates the degree of loop optimization performed by Microsoft C 5.0 (see figure 3). The compiler applied strength reduction and completely removed the constant multiplies, determined the termination state of variables *j5* and *k5*, and enregistered all variables within the loop.

Another good example of loop optimization by Microsoft C 5.0 is reflected in the **unnecessary_loop** function. The C 5.0 compiler eliminated the **for loop** and generated code only in order to satisfy the termination state of the loop-index variable and the statement embodied in the loop. The compiler also used registers well.

Microsoft's attention to optimization pays off in the performance benchmarks. It turns in times that are at or near the top in every category.

Microsoft QuickC. When it comes to code optimization, QuickC is as naive as C 5.0 is sophisticated. The code generated by the QuickC compiler was almost literal, complete with redundant loads, dead stores, and jumps to jumps. The compiler applied only the most basic optimizations, constant folding, and some algebraic simplification. It generated dead code, placed a jump around it, and failed to perform jump-chain compression.

To its credit, the compiler handled function prologues and epilogues intelligently, using discrete instructions for establishing stack-frame addressability on entry and LEAVE instructions upon exiting. Only registers used in the body of a function are pushed upon entry and popped on exit.

QuickC was included in this review because it has a command-line optimization switch (-O*x*). Given the literal nature of the code it generates QuickC was clearly designed to be a fast prototyping compiler and not an optimizing compiler.

WATCOM. The newest contender jockeying for position in the C compiler market is WATCOM C 6.0 (see this month's Product Watch by Philip N. Hisley, p. 140). C 6.0 produced tight code that makes excellent use of the rather limited register complement of the 80*x*86 family. Besides performing fundamental optimizations, it supported strength reduction and dead-code and common-subexpression elimination.

Whereas Microsoft addressed performance improvement of its compiler through loop optimization, WATCOM

gained speed by cutting function-call overhead to an absolute minimum. It achieved this feat by foregoing stack parameter passing and instead passed function parameters in registers.

WATCOM's dead-code elimination was ruthless. Not only did C 6.0 remove the dead store and the dead code within the function, it also eliminated the function prologue and epilogue and reduced the entire function to a simple return by tagging the function name onto the return instruction of the main function. To complete the task, the compiler eliminated the local call to the function.

As sophisticated as C 6.0 is in expunging the dead function, it failed to eliminate the simple duplicate dead-store situation. Just as with Optimum-C, the most significant area that WATCOM C 6.0 failed to address is loop optimization. It did not support invariant-code motion or loop-induction elimination. Although C 6.0 did not perform discrete-loop unrolling, it (along with the Datalight Optimum-C and Computer Innovations C86Plus) did use the 80x86 REP/STOSW instruction sequence to initialize the test array, thereby eliminating the loop.

WATCOM's excellent code generation, particularly the intelligent use of registers, gave it an important edge. In the performance benchmarks, it won the majority of the CPU-intensive tests and turned in better times for the large model than most of the others could muster for the small model. WATCOM's weakness was in file I/O, using **getc** and **putc**; it came in near the back of the pack on these tests.

THE LEADERS EMERGE

By the prevailing definition, any compiler that does not produce a literal translation of the source code is performing some form of optimization, even if the transformation is as low-level as constant folding. The minimum level of acceptable optimization will rise as commercially available code-generation technology provides more sophisticated and better optimizing techniques. At today's level of technology, common-subexpression elimination represents a minimum level of acceptable optimization. This level assumes that compilers that do perform common-subexpression elimination also will perform fundamental optimizations, such as constant folding and arithmetic simplification.

Even with a minimum level established, evaluating individual compiler capabilities is complicated by the many disparate forms of optimization. A compiler might use registers well but not support common subexpression elimination. Because optimizing code depends not only on applied techniques but also on the structure of the code being optimized, it is generally misleading to imply that one compiler is better than another solely by looking at isolated test cases.

TABLE 2: ***Optimization Benchmark Summary***

	BORLAND	COMPUTER INNOVATIONS	DATALIGHT
COMPILER	Turbo C	C86Plus	Optimum-C
VERSION	1.5	1.1	3.14
OPTIMIZATIONS			
Constant folding (integer)	●	●	●
Constant folding (float)	●	●	●
Constant propagation	○	○	●
Copy propagation	●	●	●
Arithmetic simplification	●	●	●
Divide-by-zero suppression	○	●	○
Subexpression elimination	○	○	●
Strength reduction	●	●	●
Redundant-load/store elimination	●	○	●
Dead-code elimination	●	●	●
Dead-store elimination	○	●	●
Machine-specific instructions used	○	●	○
Intrinsic function support	○	○	○
Enregistering	●	●	●
Native floating-point usage	●	●	●
Jump-chain compression	●	○	●
Invariant-code motion	○	○	○
Loop-induction-variable elimination	○	○	○
Loop elimination	○	○	○
Very busy expression elimination	○	○	○
Loop unrolling	○	○	○
Loop jamming	○	○	○

● = *Yes* ○ = *No*

Although all nine compilers that were reviewed generate serviceable code, three of them—Datalight Optimum-C, Microsoft C 5.0, and WATCOM C 6.0—perform code optimizations that stand above the others.

The Datalight Optimum-C compiler is a fast and impressive performer. It does extensive data-flow analysis and optimizes code that the other compilers do not even touch.

Microsoft C 5.0 addresses loop optimization, which is one area with great potential for improving code performance. By applying invariant-code motion, the elimination of loop-induction variables, and very good enregistering, Microsoft C 5.0 consistently produces excellent code.

The WATCOM C 6.0 compiler rivals Microsoft C 5.0 in the degree of optimization it performs and actually generates the fastest code in the *PC Tech Journal* optimization benchmark. What WATCOM loses in less-than-optimal loops, it more than makes up in low function-call overhead. WATCOM C 6.0 uses registers well, minimizing memory accesses and improving performance.

Both Metaware High C and Computer Innovations C86Plus perform a respectable degree of optimization but are rapidly losing ground to the advances made in compiler technology by Datalight, Microsoft, and WATCOM.

No single vendor has the corner on optimization techniques for C compilers. Competitiveness in the market is forcing compiler vendors to extend technology and to provide the systems developer with better and more sophisticated C language tools. In the future, this sophistication could mean optimizing compilers that provide even faster and tighter code.

Philip N. Hisley is a technical editor for PC Tech Journal, *specializing in languages.*

LATTICE	MANX	METAWARE	MICROSOFT		WATCOM
MS-DOS C 3.2	Aztec C 4.0	High C 1.4	C 5.0	QuickC 1.0	WATCOM C 6.0
●	●	●	●	●	●
●	●	●	●	●	●
○	○	●	●	○	●
●	●	●	●	○	●
●	●	●	●	●	●
○	○	●	●	○	●
●	●	●	●	○	●
●	●	●	●	●	●
●	●	●	●	○	●
●	○	●	●	○	●
○	○	●	●	○	●
●	○	●	●	●	●
○	○	○	●	○	●
●	●	●	●	●	●
●	●	●	●	○	●
●	○	●	●	○	●
○	○	○	●	○	○
○	○	○	●	○	○
○	○	○	●	○	○
○	○	○	○	○	○
○	○	○	○	○	○
○	○	○	○	○	○

While most of the C language compilers reviewed support simple forms of optimization, such as constant folding and arithmetic simplification, only a few of them attempt more complex forms, such as common subexpression elimination.

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Tinton Falls, NJ 07724
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C86Plus 1.1
CIRCLE 339 ON READER SERVICE CARD

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Suite 304
Bothell, WA 98011
800/221-6630; 206/486-8086
Optimum-C 3.14
CIRCLE 340 ON READER SERVICE CARD

Lattice Inc.
2500 S. Highland Avenue,
Suite 300
Lombard, IL 60148
800/533-3577; 312/916-1600
MS-DOS C 3.2
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800/221-0440
Aztec C86 4.0
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High C 1.4
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Microsoft C 5.0; QuickC 1.0
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WATCOM Products Inc.
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Waterloo, Ontario, CD N2L 3X2
519/886-3700
WATCOM C 6.0
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LISTING 1: OPTBENCH.C

```
/* ------------------------------------------------------ *
 |                                                        |
 |    PC Tech Journal Benchmark Series                    |
 |    C Code Optimization Benchmark                       |
 |                                                        |
 |    Copyright (c) 1988 Ziff-Davis Publishing Company    |
 |                                                        |
 |    This benchmark code is designed to test the         |
 |    code optimization techniques applied by a C         |
 |    compiler.  It does not produce meaningful results   |
 |    when executed, or represent good style.             |
 |                                                        |
 * ------------------------------------------------------ */

#include <stdio.h>
#include <string.h>
#define max_vector   2
#define constant5    5

typedef    unsigned char    uchar;

int     i,  j,  k , l,  m;
int     i2, j2, k2;
int     g3, h3, i3, k3, m3;
int     i4, j4;
int     i5, j5, k5;

double flt_1, flt_2, flt_3, flt_4, flt_5, flt_6;

int     ivector[ 3 ];
uchar   ivector2[ 3 ];
short   ivector4[ 6 ];
int     ivector5[ 100 ];

#ifndef NO_PROTOTYPES
void    dead_code( int, char * );
void    unnecessary_loop( void );
void    loop_jamming( int );
void    loop_unrolling( int );
int     jump_compression ( int, int, int, int, int );
#else
void    dead_code();
void    unnecessary_loop();
void    loop_jamming();
void    loop_unrolling();
int     jump_compression();
#endif

int     main( argc, argv )      /* optbench */
        int  argc;
        char     **argv;
        {
        /* ---------------------------- *
         | Constant and copy propagation  |
         * ---------------------------- */

        j4 = 2;
        if( i2 < j4 && i4 < j4 )
           i5 = 2;

        j4 = k5;
        if( i2 < j4 && i4 < j4 )
           i5 = 3;

        /* ---------------------------------------- *
         | Constant folding, arithmetic identities |
         | and redundant load/store operations      |
         * ---------------------------------------- */

        i3 = 1 + 2;
        flt_1 = 2.4 + 6.3;
        i2 = 5;
        j2 = i + 0;
        k2 = i / 1;
        i4 = i * 1;
        i5 = i * 0;
```

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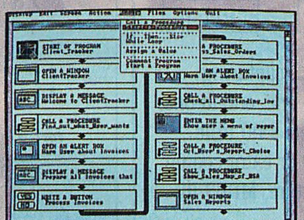

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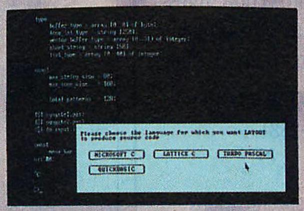

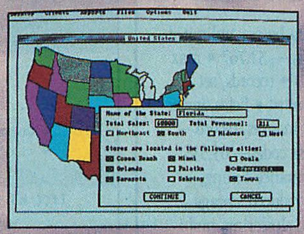

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```
#ifndef NO_ZERO_DIVIDE
        /*
         *  Some compilers correctly recognize a zero divide
         *  error and do not generate any object code.
         */
        i2 = i / 0;
        flt_2 = flt_1 / 0.0;
#else
        printf( "This compiler handles divide-by-zero as an error\n");
#endif
        flt_3 = 2.4 / 1.0;
        flt_4 = 1.0 + 0.0000001;
        flt_5 = flt_6 * 0.0;
        flt_6 = flt_2 * flt_3;

        /* ----------- *
         | Dead store  |
         * ----------- */

         k3 = 1;
         k3 = 1;

        /* -------------------- *
         | Strength reduction   |
         * -------------------- */

        k2 = 4 * j5;
        for( i = 0; i <= 5; i++ )
           ivector4[ i ] = i * 2;

    /* ---------- *
     | Simple loop |
     * ---------- */

    j5 = 0;
    k5 = 10000;
    do {
           k5 = k5 - 1;
           j5 = j5 + 1;
           i5 = ( k5 * 3 ) / ( j5 * constant5 );
       } while ( k5 > 0 );

    /* --------------------------------- *
     | Loop induction variable handling   |
     * --------------------------------- */

    for( i = 0; i < 100; i++)
        ivector5[ i * 2 + 3 ] = 5;

    /* --------------------------- *
     | Very busy expression handling |
     * --------------------------- */

    if( i < 10 )
        j5 = i5 + i2;
    else
        k5 = i5 + i2;

    /* ------------------------------------------ *
     | Check how the compiler generates the address |
     | of a variable with a constant subscript,     |
     | copy propagation, and register propagation.  |
     * ------------------------------------------ */

     ivector[ 0  ] = 1;  /* constant address generation */
     ivector[ i2 ] = 2;  /* i2 should be a propagated value */
     ivector[ i2 ] = 2;  /* register propagation */
     ivector[ 2  ] = 3;  /* constant address generation */


     /* --------------------------------- *
      | Common subexpression elimination   |
      * --------------------------------- */

    if(( h3 + k3 ) < 0 || ( h3 + k3 ) > 5 )
           printf("Common subexpression elimination\n");
    else {
           m3 = ( h3 + k3 ) / i3;
           g3 = i3 + (h3 + k3);
     }
```

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```
    /* ------------------------------------ *
     | Invariant code motion                |
     | (j * k) can be moved outside the loop. |
     * ------------------------------------ */

    for( i4 = 0; i4 <= max_vector; i4++ )
        ivector2[ i4 ] = j * k;

    /* --------------------------- *
     | Function call with arguments |
     * --------------------------- */

    dead_code( 1, "This line should not be printed" );

    /* ------------------------------ *
     | Function call without arguments |
     * ------------------------------ */

    unnecessary_loop();

    } /* end of main */

/* ----------------------------------------------- *
 | Function: dead_code                              |
 |      Test for dead code and dead stores.         |
 |      NO code should be generated.                |
 * ----------------------------------------------- */
void    dead_code( a, b )
        int a;
        char *b;
        {
        int idead_store;

        idead_store = a;
        if( 0 )
            printf( "%s\n", b );
        } /* end of dead_code */
```

```
/* ------------------------------------------------ *
 | Function: unnecessary_loop                        |
 |          The loop in the following function is   |
 |          not necessary since the value of the    |
 |          assignment is constant. Ideally, the    |
 |          loop should be optimized out.           |
 * ------------------------------------------------ */

void    unnecessary_loop()
        {
        int x;

        x = 0;
        for( i = 0; i < 5; i++ ) /* loop should not be generated */
            k5 = x + j5;
        } /* end of unnecessary_loop */

/* --------------------------------------------- *
 | Function: loop_jamming                         |
 |          The two loop in this function share   |
 |          the same loop conditions and could    |
 |          be coalesced together.                |
 * --------------------------------------------- */

void    loop_jamming( x )
        int x;
        {
        for( i = 0; i < 5; i++ )
            k5 = x + j5 * i;
        for( i = 0; i < 5; i++ )
            i5 = x * k5 * i;
        } /* end of loop_jamming */

/* ------------------------------------------------ *
 | Function: loop_unrolling                          |
 |          The loop in this function should be      |
 |          replaced with three inline word stores   |
 |          using constant array arithmetic or by    |
 |          specialized machine instructions used    |
 |          for block memory initializiation.        |
 * ------------------------------------------------ */

void    loop_unrolling( x )
        int x;
        {
        for( i = 0; i < 6; i++ )
            ivector4[ i ] = 0;
        } /* end of loop_unrolling */

/* ------------------------------------------------ *
 | Function: jump_compression                        |
 |          This awkward code is useful to illustrate |
 |          jump chain compression. The goto 'end_1' can |
 |          be replaced by a direct jump to 'beg_1'.  |
 * ------------------------------------------------ */

int     jump_compression ( i, j, k, l, m )
int i,j ,l, m;
        {
beg_1:
        if( i < j )
            if( j < k )
                if( k < l )
                    if ( l < m )
                        l += m;
                    else
                        goto end_1;
                else
                    k += l;
            else {
                j += k;
end_1:          goto beg_1;
                }
        else
            i += j;
        return( i + j + k + l + m );
        } /* end of jump_compression */
```

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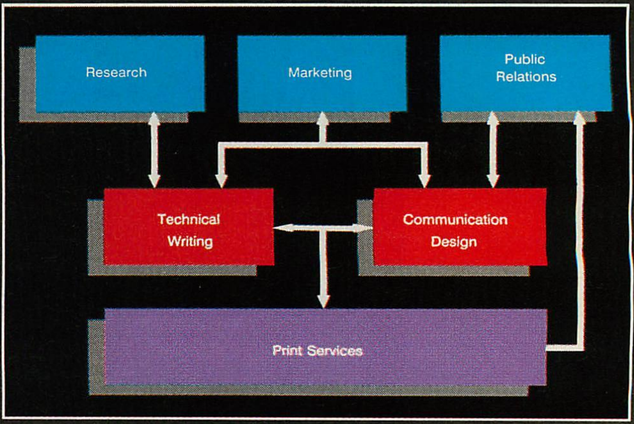

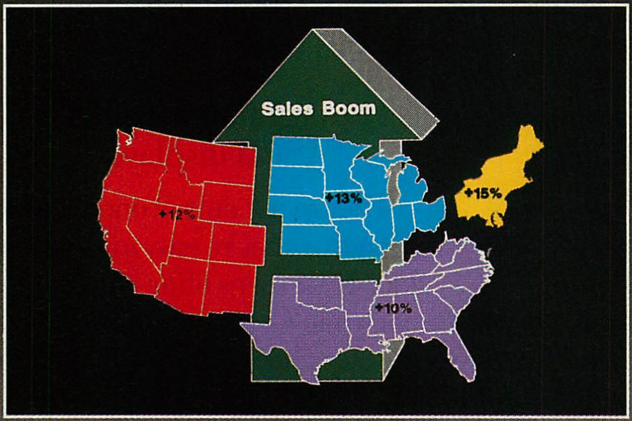

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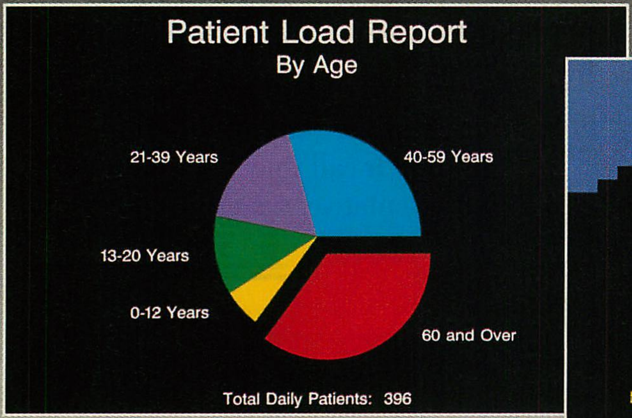

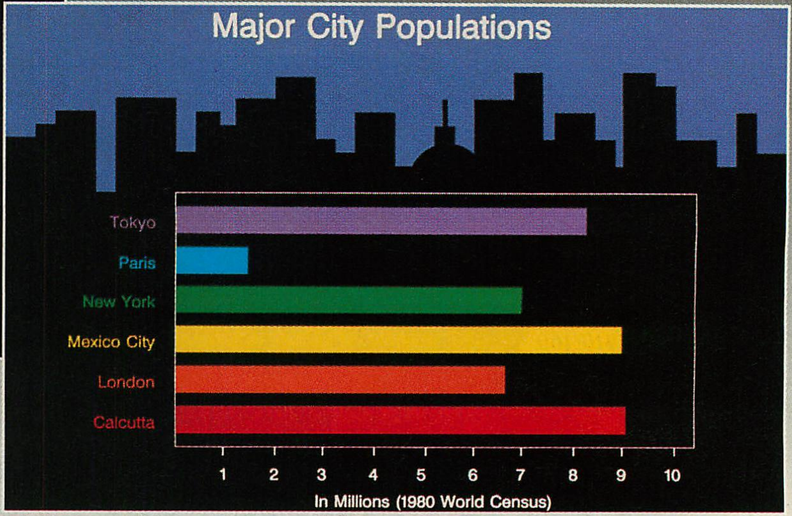

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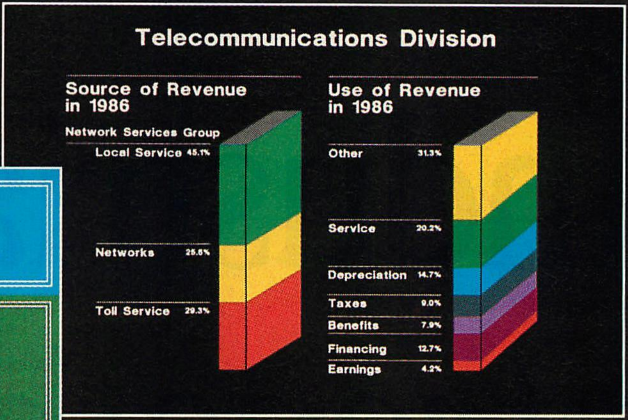
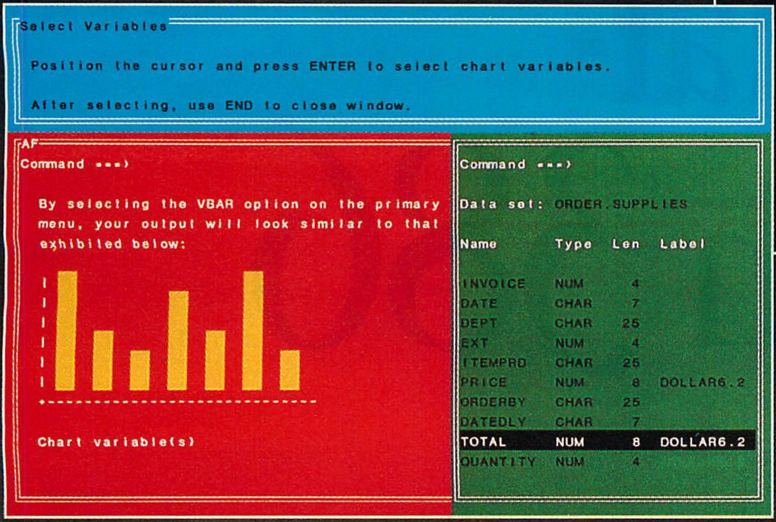
System





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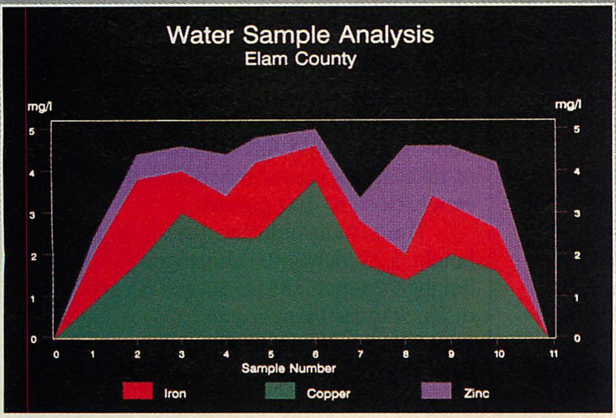

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COMPUTER SYSTEMS

386

COMPATIBILITY
PERFORMANCE

ALR's FlexCache 20386 will appeal to power users favoring speed and affordability over extensive options, technical manuals, and software support.

Industrial-Strength 386

DAVID CLAIBORNE

To survive in the highly competitive personal computer market dominated by IBM, a computer manufacturer has to serve a niche of the market better than anyone else. Advanced Logic Research Inc. (ALR) of Irvine, California, is pursuing two niches with its industrial-strength FlexCache series of 80386-based PCs. The first niche is the power user who wants maximum hardware performance for each dollar spent. The second is the original equipment manufacturer and value-added retailer (OEM/VAR) who need highly customized systems.

ALR's FlexCache 20386 meets the needs of both niches. It is a 20-MHz, 80386-based computer that runs slightly faster than the Compaq 386/20, as the *PC Tech Journal* benchmarks show. In the PC market, the FlexCache 20386 yields the highest number of MIPS (million instructions per second) per dollar. At $10,000 with a 300MB hard disk, it costs about $3,000 less than a comparably equipped Compaq.

The FlexCache 20386 is designed with the expansion capability and flexibility required to satisfy the needs of many OEMs and VARs. ALR has the ability to quickly customize its machines to meet special requirements, yet is small enough that its engineers can personally interact with OEM and VAR customers to develop custom packages.

The FlexCache series evolved from ALR's introduction of the ALR Access 386 in July 1986. The Access 386 was the first PC to use the Intel 80386 microprocessor. Using the Intel iSBC 386AT system board, with its 16-MHz CPU and interleaved memory, the Access 386 gives good performance at a reasonable price (see "ALR Access 386: Poised for Tomorrow," Michael Abrash and Dan Illowsky, April 1987, p. 104). Subsequently, ALR designed its own system board, adding 80-nanosecond (ns) dynamic RAM (DRAM) on a 32-bit, 20-MHz bus, to create the 386/220.

ALR then reworked the 386/220 to produce its FlexCache series. Available in a 16-MHz version (the 16386) as well as the 20-MHz 20386, FlexCache computers incorporate the same Intel 82385 memory cache controller used in the Compaq Deskpro 386/20 (see "Full Speed Ahead," David Claiborne, March 1988, p. 90). FlexCache uses the memory cache controller and new, high-performance disk drives with an enhanced small device interface (ESDI) controller. The use of the Intel 82385 cache controller and a 32KB static RAM (SRAM) memory cache allows the 386 processor to access the contents of frequently used memory locations from the cache with zero wait states inserted.

The FlexCache 20386 is a large computer—7.5 inches wide, 17 inches long, and 26 inches high. Its sheet-metal construction, while functional, will not win any beauty contests in an office environment. It is installed upright, resting on an 11-inch-wide stand, and is notably heavy, weighing more than 65 pounds in the review configuration. Adding a large multisynchronous monitor and full complement of disk drives makes the total system weigh close to 100 pounds.

The system unit has three half-height 5.25-inch slots, and two full-height 5.25-inch slots reserved for hard disks. Standard configuration is a single 1.2MB 5.25-inch drive and one of three hard disks (100MB, 150MB, or 300MB).

PHOTOGRAPHY • MARC DAVID COHEN


FlexCache 20386
CASPER

PHOTO 1: *Rear of the System Unit*

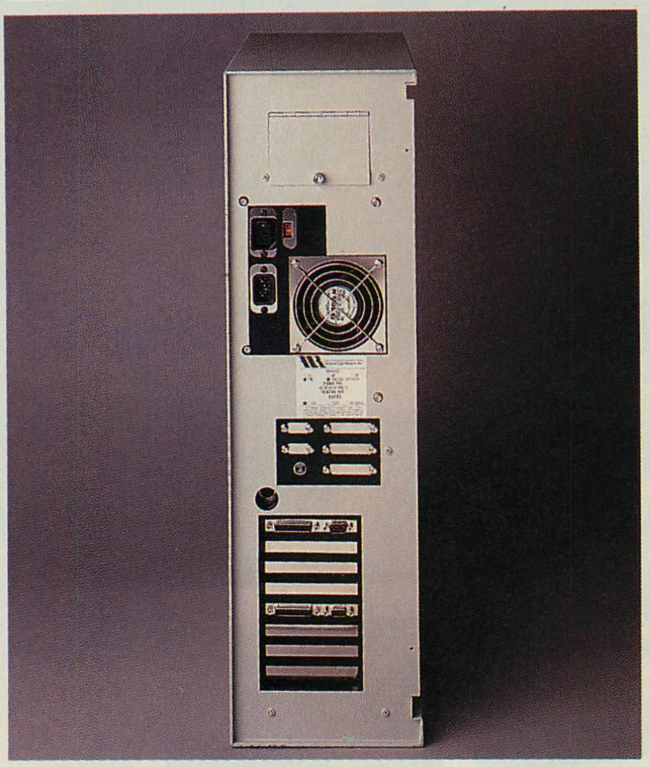


PHOTO 3: *Inside the System Unit*

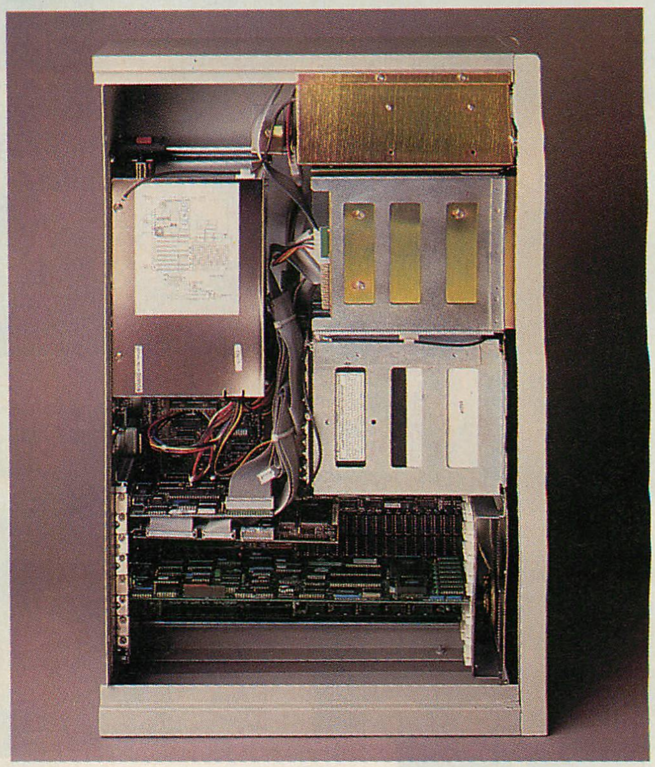


PHOTO 2: *Keyboard Comparison*

PHOTO 4: *System Board*

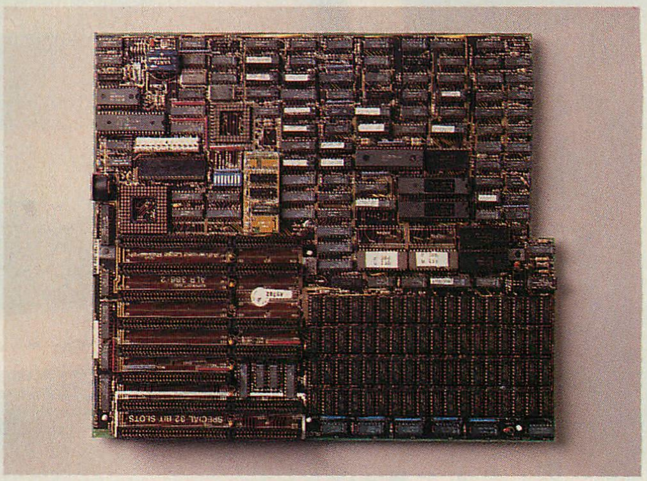


Photo 1: The power on/off switch is concealed behind a screw-down door near the top of the system unit. The power supply features an auxiliary power connector.

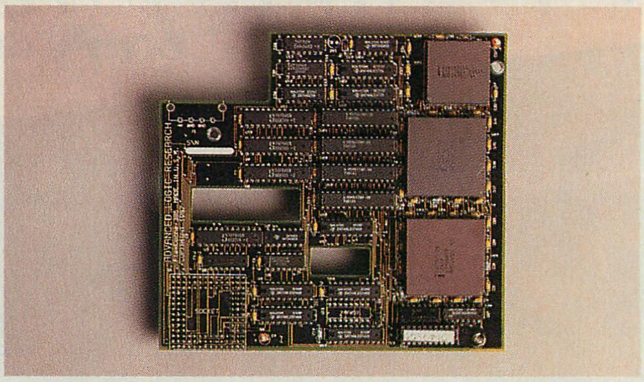
Photo 2: The FlexCache keyboard has 12 function keys across the top, and a large Enter key with the backslash (\) key and small backspace key above it, making its layout incompatible with both the IBM 84- and 101-key keyboards.

Photo 3: Adequate room for expansion is provided. Two half-height 5.25-inch diskette drive bays are available in addition to the central AT-size chassis.

Photo 4: The bottom two expansion slots are reserved for use with a pair of ALR memory boards. No other extended memory boards can be used on the expansion bus.

Photo 5: This board contains the system's Intel 20-MHz 80386, 82385 cache controller, 32KB static RAM memory cache, and an optional 80387 math coprocessor. The board connects to the system board's 80386 socket.

PHOTO 5: *CPU and Cache Controller*



The 150MB drive is the fastest, providing average access times less than 20 ms; the other two drives have access times averaging 30 ms.

The potential suitability of the FlexCache 20386 as a network file server is aptly demonstrated by a key lock on the front and the on/off switch concealed behind a screw-down door on rear of the unit (photo 1). The concealed switch can be aggravating to reach if the machine must be turned on and off frequently. Communications connectors can be installed in five blanked-off holes (three DB-25 and two DB-9) in the center of the back panel.

The ME-101 Maxiswitch keyboard, made by EECO Inc., uses the enhanced 101-key IBM AT layout, but with several twists of its own. The CapsLock and Ctrl key locations on the left side can be switched so that WordStar aficionados can hit Ctrl-key combinations with one hand. The keyboard uses the large Enter key, with the backslash (\) key and small Backspace key above it, as does the IBM 84-key keyboard. On the IBM 101-key keyboard (see photo 2), the \ key is located between the Enter and backspace keys.

Users familiar with an 84-key keyboard will have difficulty finding the special function keys on this keyboard, and users familiar with a standard 101-key keyboard will find themselves pressing Enter when attempting to press the \ key. While this might not be a significant problem if the machine is used as a file server, workstation users should carefully consider whether this keyboard is really appropriate for them. By attempting to provide desirable features from both the 84- and 101-key keyboards, the ALR keyboard is compatible with neither.

The keyboard's rubber-dome technology provides reasonable tactile feedback, and the audible click is easily adjusted with Ctrl-Alt-up and Ctrl-Alt-down arrows. The default state at boot-up is silent keys. The cable connecting the keyboard to the computer is long enough to allow the computer to be placed under a desk, but, at only four feet coiled, it is not as long as the 10-foot keyboard cable used on the IBM PS/2 Model 80. In addition, the cable cannot be detached from the keyboard—another incompatibility with the IBM 101-key enhanced keyboard.

ALR offers an optional Hercules-compatible monochrome graphics adapter (MGA) or an IBM-compatible EGA for use with the 20386. Both boards contain an IBM-compatible printer port. The EGA board, supplied with the review unit, uses the Chips & Technologies' chip set; the EGA display was a Casper Model TE5154.

Because ALR does not make small computers and aims its products at the commercial market and the power user, the company obtains for its computers only Class-A (commercial-use) certification from the Federal Communications Commission (FCC). In addition, many FlexCache internal components, such as disk drives, are only Class-A certified.

ALR's proprietary memory boards expand system memory to 10MB. Boards come in pairs and each contains a serial port and a parallel port. Prices for the base units and available options are shown in the sidebar, "ALR FlexCache 20386 Vital Statistics." Options included with the evaluation unit are marked with an asterisk (*).

GETTING READY

Installation and setup of the FlexCache 20386 is straightforward. Users install the floor stand using four supplied screws; once it is attached, the unit is steady when upright. The system's weight prevents it from being moved again without difficulty.

Its configuration is controlled by a single bank of DIP switches, mounted on an accessible area of the system board and free of any expansion boards. The switches set the size of the system board memory, signal the presence or absence of an 80387 math coprocessor, turn the cache controller on or off, set the default CPU speed at system initialization, and determine the default display adapter type. A graphical menu explaining the configuration setting is displayed conveniently on top of the power supply.

Additional configuration switches are present on disk controllers and I/O boards. In general, these switches are set at the factory; if changes are required later, instructions are provided in the documentation.

System board memory is contained in four rows of 18 sockets that are easy to reach if no boards are installed in expansion slots. The standard computer has 1MB of 80-ns RAM. An additional 1MB can be added to the system board, but 80-ns memory must be used.

The FlexCache 20386 allows for a cornucopia of storage devices. The unit has three half-height 5.25-inch bays for installing diskette drives or a streaming tape backup, and two full-height 5.25-inch bays for hard-disk drives (see photo 3). The power supply, rated at a hefty 225 watts, has the capacity to operate a full complement of drives. The capacities of the power supply and disk controllers, as well as the physical arrangement inside the unit, allow third-party drives to be added with relative ease. The system BIOS supports the 47 disk types shown in table 1.

The standard unit contains a multipurpose I/O controller that controls two diskette drives (5.25-inch or 3.5-inch) plus a serial port and a parallel port. The default drive (drive A:) can be either a 5.25-inch or 3.5-inch drive. One 1.2MB 5.25-inch drive is provided as standard equipment; the 1.44MB 3.5-inch diskette drive can be added as

ALR FLEXCACHE 20386 VITAL STATISTICS

Model 100: $6,490
1MB memory
32KB SRAM cache
Serial and parallel interfaces
Realtime clock
1.2MB diskette drive
Enhanced keyboard
80387 socket
100MB hard disk
***Model 150: $7,490**
All features of Model 100 except with 150MB hard disk and ESDI controller
Model 300: $9,990
All features of Model 100 except with 300MB hard disk and ESDI controller
Internal memory capacity:
10MB
Available slots:
8/16-bit: 2
8-bit: 1

Available options:
*Casper EGA color monitor: $699
*ALR enhanced graphics adapter: $399
ALR monochrome graphics adapter: $179
*80387 math coprocessor (20-MHz version): $1,195
*1MB, 80-ns RAM kit: $650
1MB/4MB, 80-ns memory expansion board set: $975
4MB, 80-ns memory expansion board set: $2,499
Additional 150MB disk drive: $2,999
Additional 300MB disk drive: $4,555
*1.44MB 3.5-inch diskette drive: $225
130MB tape backup drive: $1,995
*MS-DOS/BASIC 3.3: $120

An asterisk (*) indicates the model reviewed and the options included. The announced retail price of that model with those options is $10,778.

TABLE 1: *Disk Drives Supported*

DRIVE TYPE	NO. OF CYLINDERS	NO. OF HEADS	CAPACITY (MB)	LANDING ZONE CYLINDER	PRECOMPENSATION CYLINDER[a]	SECTORS/ TRACK
1	306	4	10.1	305	128	17
2	615	4	20.4	615	300	17
3	615	6	30.6	615	300	17
4	940	8	62.4	940	512	17
5	940	6	46.8	940	512	17
6	1,160	7	103.0	1,160	−1	26
7	462	8	30.6	511	256	17
8	733	5	30.4	733	−1	17
9	900	15	112.0	901	−1	17
10	820	3	20.4	820	−1	17
11	855	5	35.4	855	−1	17
12	855	7	49.6	855	−1	17
13	306	8	20.3	319	128	17
14	733	7	42.5	733	−1	17
15	Reserved					
16	612	4	20.3	663	0	17
17	977	5	40.5	977	300	17
18	977	7	56.7	977	−1	17
19	1,024	7	59.5	1,023	512	17
20	823	10	136.6	823	−1	34
21	733	7	42.5	732	300	17
22	971	5	60.0	971	−1	26
23	306	4	10.1	336	0	17
24	Reserved					
25	615	4	20.4	615	0	17
26	1,024	4	34.0	1,023	−1	17
27	1,024	5	42.5	1,023	−1	17
28	1,024	8	68.0	1,023	−1	17
29	512	8	34.0	512	256	17
30	1,160	7	103.0	904	−1	26
31	989	5	41.0	989	128	17
32	1,020	15	127.0	1,024	−1	17
33	Reserved					
34	966	9	144.3	966	−1	34
35	966	8	128.2	966	−1	34
36	1,024	5	42.5	1,024	512	17
37	1,024	5	65.0	1,024	−1	26
38	611	16	300.7	612	−1	63
39	925	9	80.0	925	−1	17
40	615	8	40.8	664	128	17
41	917	15	114.1	918	−1	17
42	1,023	15	127.0	1,024	−1	17
43	823	10	68.3	823	512	17
44	1,024	8	71.0	1,024	−1	26
45	1,024	8	68.0	1,024	−1	17
46	1,024	7	103.0	1,024	−1	26
47	966	5	58.9	966	−1	25

[a] *A value of −1 indicates that write precompensation is not used.*

The FlexCache 20386 supports 47 drive types, as compared with 23 on the 8-MHz AT. Nearly all AT drive types are supported, in addition to many larger drives not supported on the AT. Most, but not all, types are the same as for the IBM AT.

an extra-cost option. The Model 100 comes with an Adaptec run-length limited (RLL) hard-disk controller; Models 150 and 300 come with the Western Digital WD1006-WAH, an ESDI controller that provides full-track buffering to increase effective data transfer by 20 percent. Both controllers use a 1:1 interleave and can control two disk drives. A Western Digital WD1003-WA2 controller, which supports two ST506 hard-disk drives plus two 5.25-inch or 3.5-inch diskette drives, is an option.

The expansion slots in the FlexCache 20386 are tightly spaced with less than an inch between slots, and the front slot guide is permanently affixed to the case. This makes installing full-length boards an exercise in careful, artful persuasion.

The socket for the 387 is tucked into a narrow opening between the left (lower) disk-drive bay and the power supply. It is barely visible beneath the power and ribbon cables leading to the drives. As a result, the 387 should be installed at the factory or either the system board or the power supply and disk drive should be removed first.

CRACKING OPEN THE CASE

FlexCache 20386 differs from a conventional AT-compatible computer in that inside access is gained simply by removing the side cover when the system is standing on the floor, rather than sliding the entire case off. The cover is held in place with two spring-loaded thumb screws, allowing quick and easy access to the inside of the unit.

Major system components are contained in an internal AT-size chassis mounted in the system case. On the review unit, the internal chassis was securely attached to the rear of the outer case, but only loosely attached at the top and bottom.

The ALR system board features eight expansion slots (see photo 4). Expansion slots 1, 2, 4, 5, 7, and 8 use the AT bus and slots 3 and 6 use the XT bus. Slots 1 and 2 are normally occupied by the multipurpose I/O controller and the hard-disk controller, respectively. The display controller generally occupies one of the XT-bus slots. Slots 7 and 8 are reserved for ALR's proprietary 32-bit memory scheme. The result is that three slots—two AT and one XT—are available.

The AT and XT bus slots operate at 10 MHz. The Compaq Deskpro 386/20's expansion bus, on the other hand, runs at 8 MHz to maintain compatibility with boards designed for the AT. ALR claims that the FlexCache's nonstandard bus

speed is a performance feature; however, older boards designed for use with the 4.77-MHz XT bus or 6-MHz AT bus may not work properly.

ALR's 32-bit memory expansion scheme uses a matched pair of memory boards in slots 7 and 8 as a single system to produce a 32-bit data bus using standard AT-bus connectors. Only ALR boards can be used in these slots. Slot 7 is the lower 16 bits of each word; slot 8 is the upper 16 bits. Memory must be added in 1MB increments (two banks of nine 80-ns 256KB chips on each board).

ALR builds its memory expansion boards with a capacity of 2MB each, with add-on 2MB memory packs for each board. This limits system memory to 10MB (2MB on the system board and 4MB on each of the two matched memory expansion boards). Because of the nature of ALR memory architecture, no more memory can be added using the standard AT-style slots.

The add-on circuit board that transforms the 386/220 into the FlexCache connects to the system board via its original 386 socket. Three screws secure the add-on board to plastic posts glued to the system board. The add-on board contains the system's 20-MHz 386, 82385 cache controller, and 32KB memory cache. The optional 387 coprocessor is also installed on this board (see photo 5). ALR estimates that this effective, if somewhat inelegant, design provides the 386 access to information from memory at zero wait states 95 percent of the time. The cache memory is contained in four socketed, 35-ns memory devices. ALR uses sockets for all memory chips—on the system board, the FlexCache, the EGA, or memory expansion boards.

TABLE 2: ***Setup Directories***

DIRECTORY	DEVELOPER	CONTENTS
EXDSKBIO	Phoenix	Driver for 3.5-inch diskette drive under MS-DOS 3.2.
HDFORM	Western Digital	Low-level format program for hard-disk drive using the ESDI controller.
MGA	ALR	SETMODE program for software control of monochrome display mode.
MSDPATCH	Phoenix	Patch for MS-DOS 3.2 to ensure compatibility with Phoenix BIOS.
QEMM	Quarterdeck	Extended memory manager.
RLL	Phoenix	Program for Adaptec RLL disk controller.
TEST	ALR/Borland	ALR's diagnostic programs.
SPEED	Microsoft	SETSPEED program for software control of processor speed.

Each of the eight directories on the setup diskette contains a README file describing the test or utility programs that are contained in the directory.

STANDARD-ISSUE SOFTWARE

ALR provides only two software disks with the FlexCache 20386: the ALR setup disk and the Phoenix Control/386 disk. Setup and testing programs are contained in eight directories (see table 2) on the setup disk. Each directory contains a README file and the utility program (or programs).

Control/386, a collection of programs developed by Phoenix Technologies Ltd., the developer of the Flex-

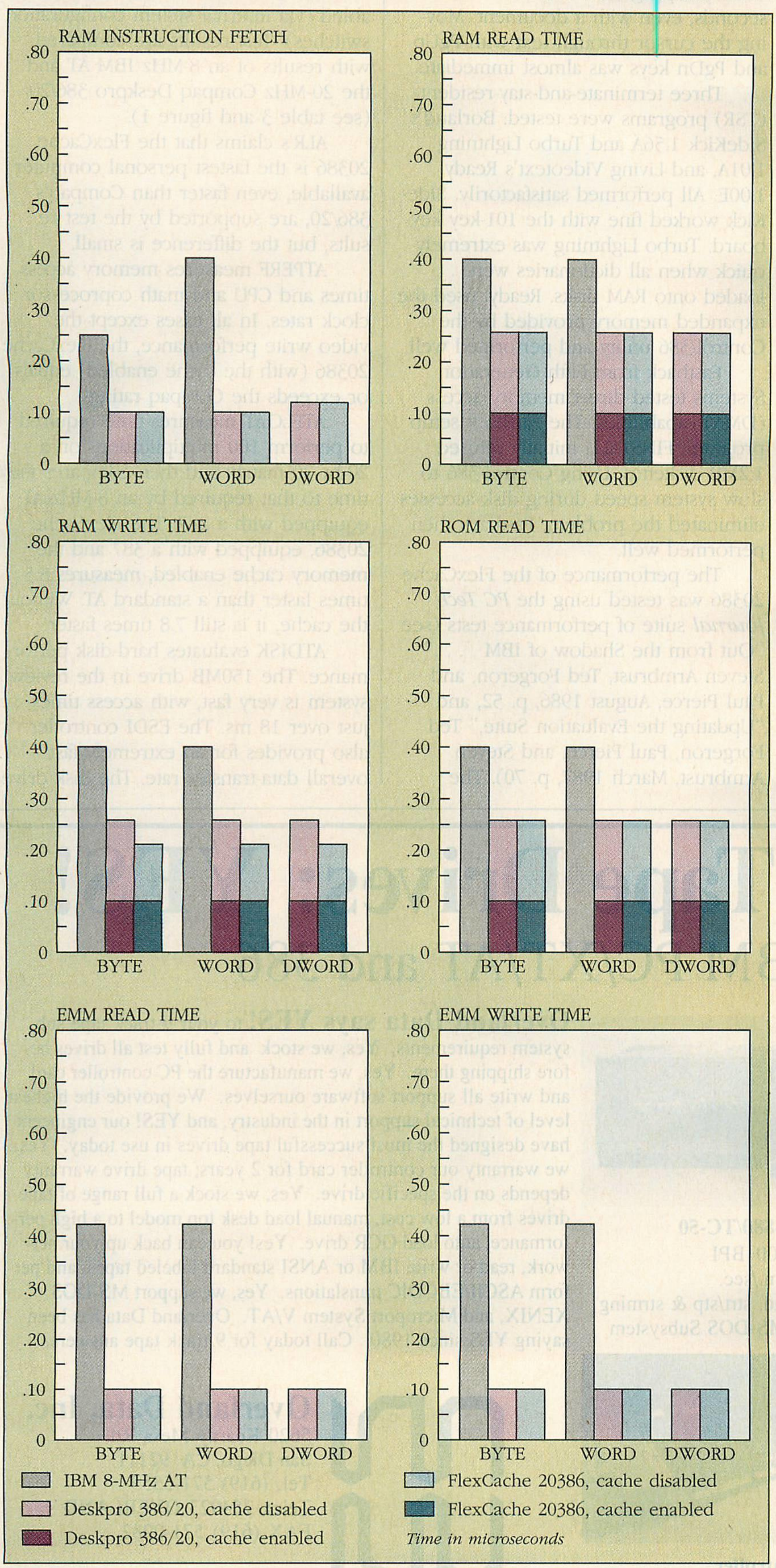
TABLE 3: *Compatibility and Performance Tests*

	8-MHz IBM AT 80287, 30MB DISK[a]	20-MHz DESKPRO 386 80387, 300MB DISK	20-MHz ALR FLEXCACHE 80387, 150MB DISK
ATBIOS			
ROM BIOS date	11/15/85	09/23/87	01/15/88
ATPERF			
Average RAM instruction fetch (μs)			
BYTE	.25	.10 (250)[b]	.10 (250)
WORD	.403	.10 (403)	.10 (403)
DWORD	N/A	.12	.12
Average RAM read time (μs)[c]			
BYTE	.401	.10/.26 (401/154)	.10/.26 (401/154)
WORD	.401	.10/.26 (401/154)	.10/.26 (401/154)
DWORD	N/A	.10/.26	.10/.26
Average RAM write time (μs)[c]			
BYTE	.401	.10/.26 (401/154)	.10/.21 (401/189)
WORD	.401	.10/.26 (401/154)	.10/.21 (401/189)
DWORD	N/A	.10/.26	.10/.21
Average ROM read time (μs)			
BYTE	.401	Same as RAM read	Same as Ram read
WORD	.401	Same as RAM read	Same as RAM read
DWORD	N/A	Same as RAM read	Same as RAM read
Average EMM read time (μs)[d]			
BYTE	.402	.10 (402)	.10 (402)
WORD	.402	.10 (402)	.10 (402)
DWORD	N/A	.10	.10
Average EMM write time (μs)[d]			
BYTE	.402	.10 (402)	.10 (402)
WORD	.402	.10 (202)	.10 (402)
DWORD	N/A	.10	.10
Average CGA video write time (μs)[e]			
BYTE	1.208	.94 (128)	1.97 (61)
WORD	2.415	1.86 (130)	3.94 (61)
DWORD	N/A	4.83	7.87
CPU clock rate (MHz)	8.0	20.0 (250)	20.0 (250)
Math coprocessor clock rate (MHz)	5.3	20.0 (377)	20.0 (377)
Refresh overhead (%)	7.1	4.4	3.8
RAM read/write wait states	1/1	0/0	0/0
ROM read wait states	1	Same as RAM read	Same as RAM read
Video write wait states (CGA)	8	16	37
EMM read/write states	1/1	0/0	0/0
ATFLOAT			
Performance relative to AT (%)	100	850	850
ATDISK			
Sectors/track	17	63	34
Heads	5	16	9
Cylinders	731	609	964
Total disk space (MB)	30.34	299.75	144.03
Track-track seek time (ms)	6.0	6.4	4.8
Average seek time (ms)	37.1	20.7	18.0
Effective transfer rate (KB/sec)	170.1	629.5	509.9
DOS File I/O with/without cache (sec)[f]	7.3	5.05/5.0	6.2/6.4
Interleave	3	1	1

[a] *The figures for the IBM AT and Compaq Deskpro 386/20 are the average results from several machines, whereas the results from the FlexCache 20386 were taken only from the review model.*
[b] *Figures shown in parentheses represent the relative performance expressed as a percentage compared with the 8-MHz, 30MB AT.*
[c] *For the Deskpro 386/20 and FlexCache 20386, the first number is for memory access with cache enabled; the second is with it disabled.*
[d] *For the Deskpro 386/20 and FlexCache 20386, EMM measurements were taken using extended memory and the expanded memory manager driver provided with the system.*
[e] *For the Deskpro 386/20 and Flexcache 20386, video write times were measured using the supplied EGA in CGA mode.*
[f] *Deskpro 386/20 and FlexCache 20386 were tested with/without the disk-caching program.*

The FlexCache 20386's Intel 82385 cache controller and 32KB SRAM cache allow the 20-MHz 80386 to access frequently referenced information with zero wait states inserted. Floating-point operations are eight times faster than on the 8-MHz AT.

FIGURE 1: *Performance Comparison*



The FlexCache 20386 provides the same or slightly better performance than the Deskpro 386/20. Both are approximately four times faster than the 8-MHz AT.

Cache 20386 BIOS, enhances computational performance of 386 computers. It provides disk caching, copying, and mapping of system BIOS and EGA BIOS from ROM to faster 32-bit RAM, and the use of extended memory as expanded memory. Control/386 can be activated automatically or turned on or off at boot time at the user's option.

The Quarterdeck expanded memory manager (QEMM) is not really necessary because Control/386 duplicates its functions. RLL is required for use only with the optional Adaptec RLL controller. ALR's set of diagnostic programs function in a similar manner to the IBM diagnostic suite.

The SPEED directory contains the utility SETSPEED.EXE for setting the CPU speed. The CPU runs at 20 MHz, but when the system speed is set to LO using SETSPEED, lower-speed operation is simulated by disabling the cache controller and increasing the frequency of memory refresh cycles. System speed also can be changed using a configuration switch on the system board, by using a keyboard sequence, or by writing to I/O port 64H.

A generic version of MS-DOS 3.3, which includes the GW-BASIC interpreter, is available at extra cost from ALR for use with the FlexCache 20386. PC-DOS 3.3 also can be used, but its BASIC interpreter cannot be used because it requires routines available only in IBM's ROM BIOS.

COMPATIBILITY AND SPEED

The compatibility of FlexCache 20386 with hardware and software designed for IBM PC/AT-type computers was tested by installing and using a variety of products typical of those used on many AT-compatible systems.

ALR ensures that 80-ns memory is used in the system by allowing only its extended memory boards to be recognized and used. Therefore, the Cheetah Combo extended memory board, which was used in previous compatibility and performance reviews, was not tested. An Intel Above Board AT was used as an expanded memory board without any difficulty.

Inability to install additional, standard AT-type memory boards is not, however, a severe detriment. The FlexCache 20386 comes with at least 1MB of memory, and, in general, adding memory with 16-bit expansion boards to 386 computers degrades overall performance. By adding 1MB to the system board and using the pair of ALR memory boards, system memory can be expanded to 10MB. All memory is

80-ns, accessed on a 20-MHz, 32-bit bus via a cache controller.

A Hayes internal 1200B Smartmodem (half-card version) was installed and used without difficulty. Bus and serial versions of the Microsoft mouse were tested. The serial mouse was installed in 30 seconds and worked fine, although it used one of the system's two serial ports. The bus version took longer to install, but also worked well; it used one of three available slots rather than a serial port.

The first test of software compatibility was the IBM AT Advanced Diagnostics 2.04. The FlexCache 20386 passed with two exceptions. The memory test recognized only 1,920KB of the 2,048KB present because ALR remaps 128KB of the first 1,024KB to be used as fast ROM. The coprocessor test also failed because the FlexCache 20386 uses the Intel 387, rather than a 287.

Graphics software worked without problems. Microsoft Windows/386 is not compatible with Control/386 because both programs want to be the only virtual memory manager. If the system is booted with Control/386, Windows/386 will not load. Installing Windows/386 (after Control/386 was turned off at boot time) made switching from application to application effortless. Microsoft Word 4.0 performed well. The program loaded in about two seconds, even with a document. Moving the cursor through text with PgUp and PgDn keys was almost immediate.

Three terminate-and-stay-resident (TSR) programs were tested: Borland's SideKick 1.56A and Turbo Lightning 1.01A, and Living Videotext's Ready! 1.00E. All performed satisfactorily. SideKick worked fine with the 101-key keyboard. Turbo Lightning was extremely quick when all dictionaries were loaded onto RAM disks. Ready! used the expanded memory provided by the Control/386 utility and performed well.

Fastback from Fifth Generation Systems tested direct memory access (DMA) capabilities. The Fastback setup program, FINSTALL, initially refused 1.2MB diskettes. Using Control/386 to slow system speed during disk accesses eliminated the problem. Fastback then performed well.

The performance of the FlexCache 20386 was tested using the *PC Tech Journal* suite of performance tests (see "Out from the Shadow of IBM . . . ," Steven Armbrust, Ted Forgeron, and Paul Pierce, August 1986, p. 52, and "Updating the Evaluation Suite," Ted Forgeron, Paul Pierce, and Steven Armbrust, March 1987, p. 70). The computer was tested in two modes: with the cache enabled and with it disabled (via internal system configuration switches). Test results are compared with results of an 8-MHz IBM AT and the 20-MHz Compaq Deskpro 386/20 (see table 3 and figure 1).

ALR's claims that the FlexCache 20386 is the fastest personal computer available, even faster than Compaq's 386/20, are supported by the test results, but the difference is small.

ATPERF measures memory access times and CPU and math coprocessor clock rates. In all cases except the video write performance, the FlexCache 20386 (with the cache enabled) equals or exceeds the Compaq ratings.

ATFLOAT measures time required to perform 100 multiplications on a 20-by-20 matrix and then compares the time to that required by an 8-MHz AT equipped with a 287. The FlexCache 20386, equipped with a 387 and the memory cache enabled, measures 8.5 times faster than a standard AT. Without the cache, it is still 7.8 times faster.

ATDISK evaluates hard-disk performance. The 150MB drive in the review system is very fast, with access times just over 18 ms. The ESDI controller also provides for an extremely fast overall data-transfer rate. The disk drive

and controller are so fast that Control/386's disk-caching software provides only a marginal speed improvement.

ATBIOS examines the BIOS and BIOS date. In the test, the ALR copyright date was 1/15/88. ATKEY tests AT-keyboard compatibility. The review unit passed the test, as well as the IBM AT Advanced Diagnostics keyboard test.

A SHORT PAPER TRAIL

FlexCache 20386 documentation consists only of the *FlexCache 16386/20386 User's Manual* and the *User's Guide to Control/386*. The information contained in the two manuals rivals what IBM and Compaq provide as standard documentation. These other companies, however, provide added technical information for an additional fee, whereas ALR does not.

The user's manual instructs the user on unpacking and setting up standard and optional hardware and ALR-provided software. Diagrams explain configuration switch settings on the system board, disk-controller boards, an optional EGA controller board, and ALR memory boards. Advanced topics, such as removal of the system board, are described and illustrated. Pinout lists show all external connections, including serial ports, parallel ports, and the system-board edge connector. Two tables explain the system board memory map and the I/O address map, and another table lists error messages.

The Control/386 guide, written by Phoenix Technology Ltd., describes commands that can be used in the CONFIG.SYS file to allow the use of the Control/386 programs.

FAST AND FURIOUS

ALR's FlexCache 20386 provides maximum available computational power with the 386 and the optional 387, both running at 20 MHz. By using the FlexCache memory architecture with 80-ns memory, it provides one of the fastest memory packages available. Storage, more than 600MB worth inside the system unit, exceeds the capacity of many small computer centers.

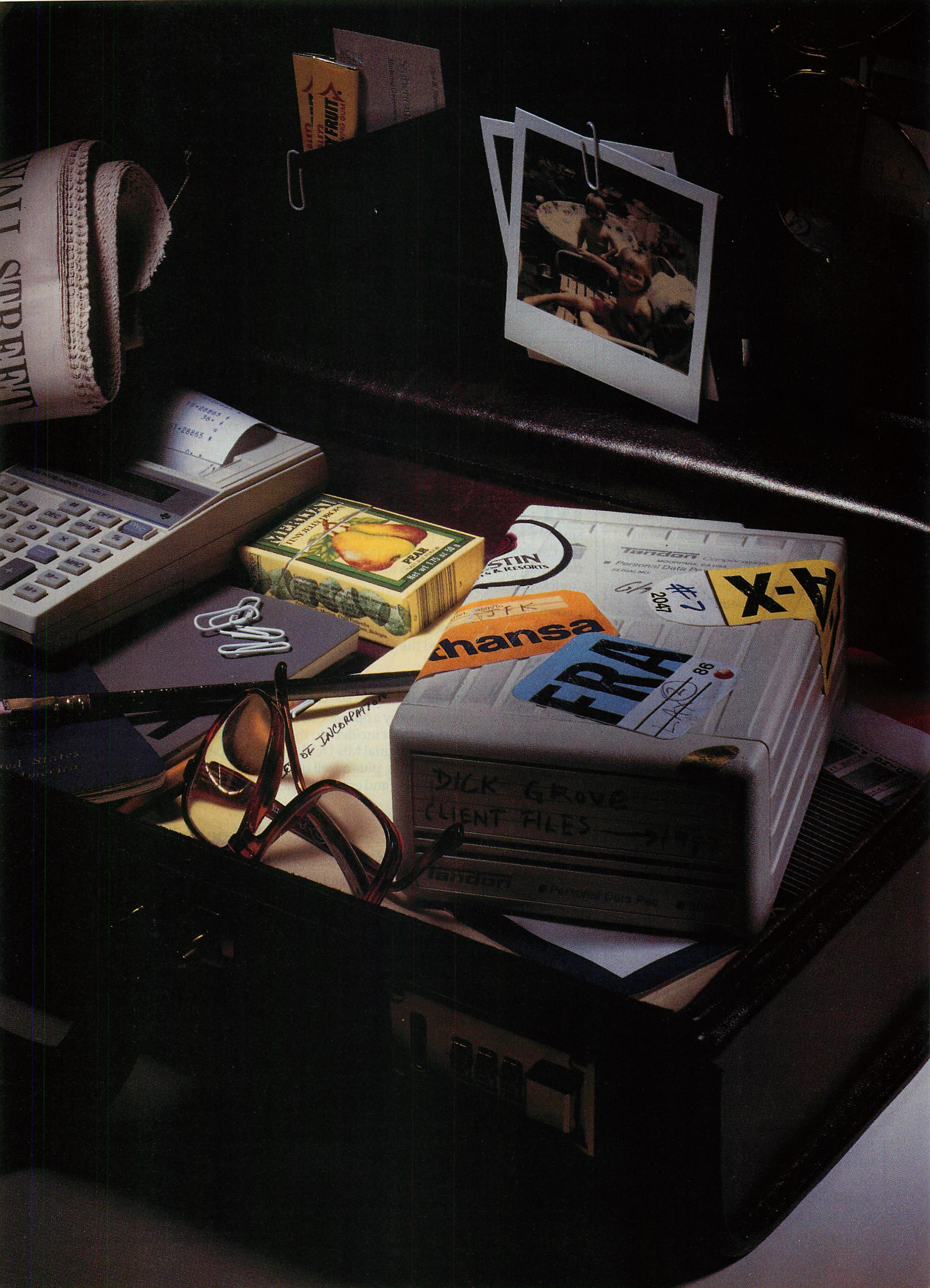
To achieve its impressive price/performance ratio, ALR makes a few sacrifices. FlexCache is certified as an FCC Class-A machine, suitable for commercial establishments only, not residential use. Its ALR-memory-board-only restriction provides 80-ns memory, but limits total memory to 10MB; its 10-MHz expansion bus operation can cause problems with older adapter boards. The company provides little in the way of software; it must be mixed and matched from third-party products. The user's manuals are written by third parties and, while adequate for setting up and running the computer, they lack the technical depth available with some other computer manuals.

The FlexCache 20386 is most suited for systems developers, OEMs, and VARs developing and installing large 386-based systems, who might find these shortcomings inconsequential compared to its striking performance and attractive price. For the experienced power user, CAD designer, or network developer who does not need extensive documentation and software support, the FlexCache 20386 is an appealing system.

Advanced Logic Research Inc.
10 Chrysler
Irvine, CA 92718
714/581-6770
FlexCache 20386

CIRCLE 331 ON READER SERVICE CARD

David Claiborne is a technical manager for JAYCOR in Edgewood, Maryland.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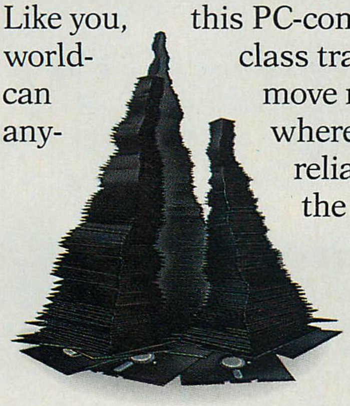

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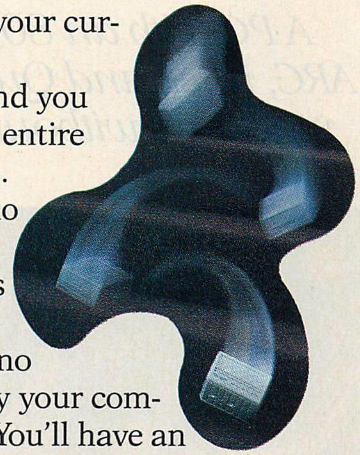
And wherever the Personal Data Pac goes, it gets along splendidly. With a single, low-cost receptacle, the Tandon Ad-PAC, you can up-grade your current PC system.



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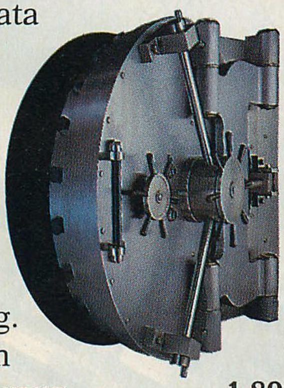

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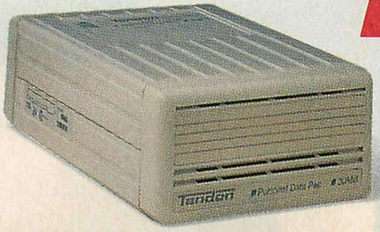
To learn more about it, see your Tandon Dealer or call us today at **1-800-556-1234**, ext. 171. In California call **1-800-441-2345**, ext. 171.



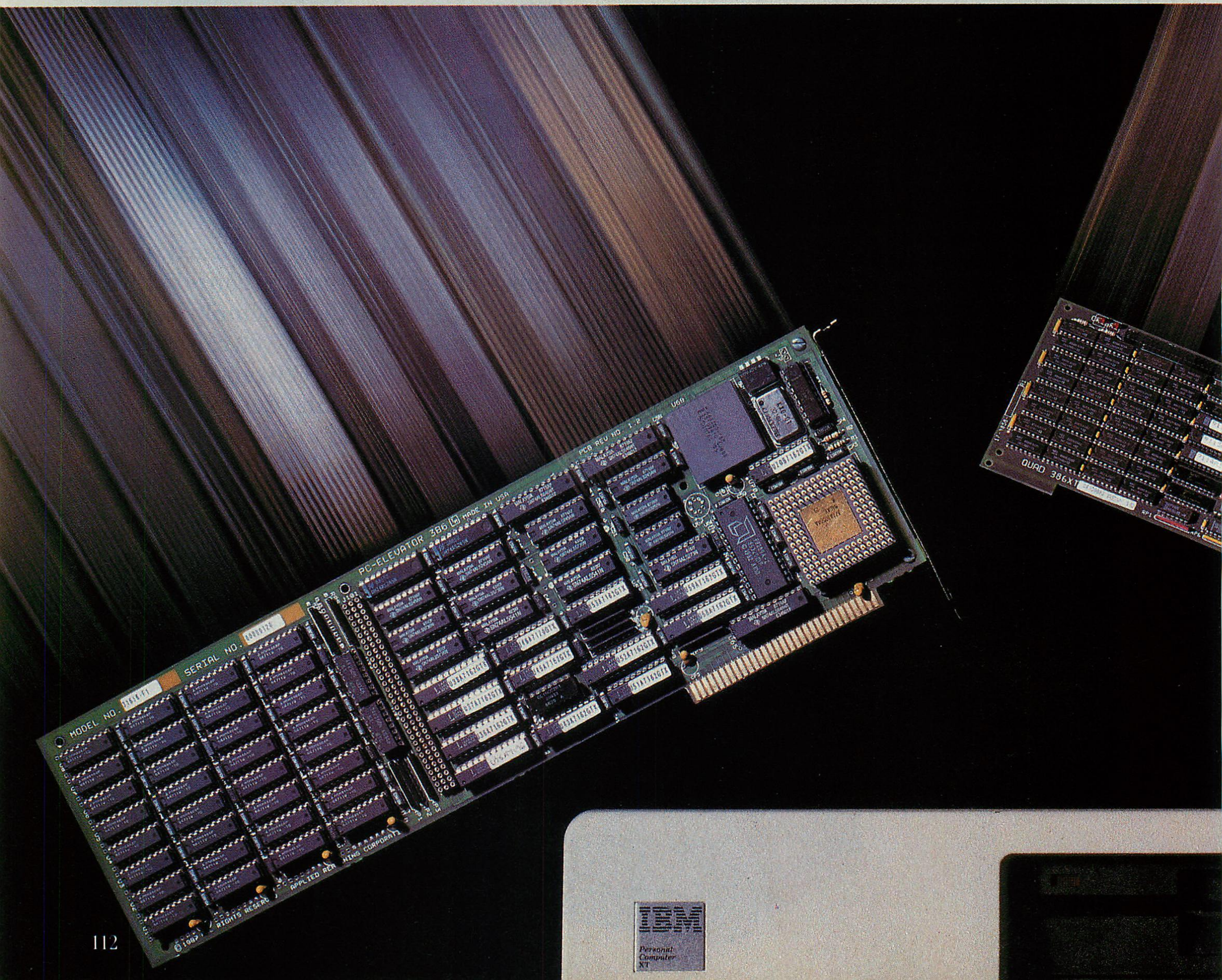
Tandon

We're redefining personal computing.

CIRCLE NO. 163 ON READER SERVICE CARD

The Souped-up PC

A PC with an 80386 accelerator is a faster PC, but it is still a PC. ARC, Intel, and Quadram add-in boards boost performance of tired machines without providing other benefits of the 386 architecture.



THOMAS V. HOFFMANN

Being a PC pioneer was fun in the beginning. In 1981, people were impressed when they found out you had a *computer*—a state-of-the-art IBM Personal Computer, generously endowed with a *full* 64KB of memory, two display adapters, a serial card, a game adapter, and one single-sided 160KB diskette drive. One slot was even left over for future expansion.

Times have obviously changed. At the office, 16-MHz 80386 machines with 4MB of fast 32-bit RAM are taking over as standard workstations. Many businesses are poised for OS/2, UNIX, and large applications. Early-model PCs are still plentiful, however, and in many homes and businesses, DOS, sub-MIP performance, and sub-megabyte software still reign.

Three recent products offer PC and PC/XT owners salvation from eternal stagnation. Applied Reasoning Corporation's (ARC) PC-Elevator 386 ($1,795), Intel's Inboard 386/PC ($995), and Quadram's Quad 386XT ($995) each provide a 16-MHz 386 processor and 1MB of fast 32-bit memory on a full-length add-in board. Each board has a daughtercard connector for 32-bit memory expansion of 2MB or more, and a socket for an 80387 math coprocessor. The characteristics and features of these three accelerator boards are listed in table 1.

Each board comes with software that uses the 386 virtual-8086 mode and memory-mapping facilities to run DOS applications in fast 32-bit memory and to set up any remaining RAM as either extended (beyond 1MB) or expanded (paged in the first megabyte) memory. The Intel and ARC products also include disk-caching software (both are OEM versions of Super PC-Kwik from Multisoft Corporation), and the Quadram package includes several RAM-disk and print-spooling programs.

Despite excitement over the possibility of upgrading to the 386 for less than $1,000, users should consider a few potential problems before rushing out to buy any of these products. First, the host system should have a power supply rated at 130 watts or more; the original 63-watt PC power supply is not likely to be sufficient. A PC-1 system (with the original 64KB system board) must have an upgraded BIOS that scans for adapter ROMs containing BIOS ex-

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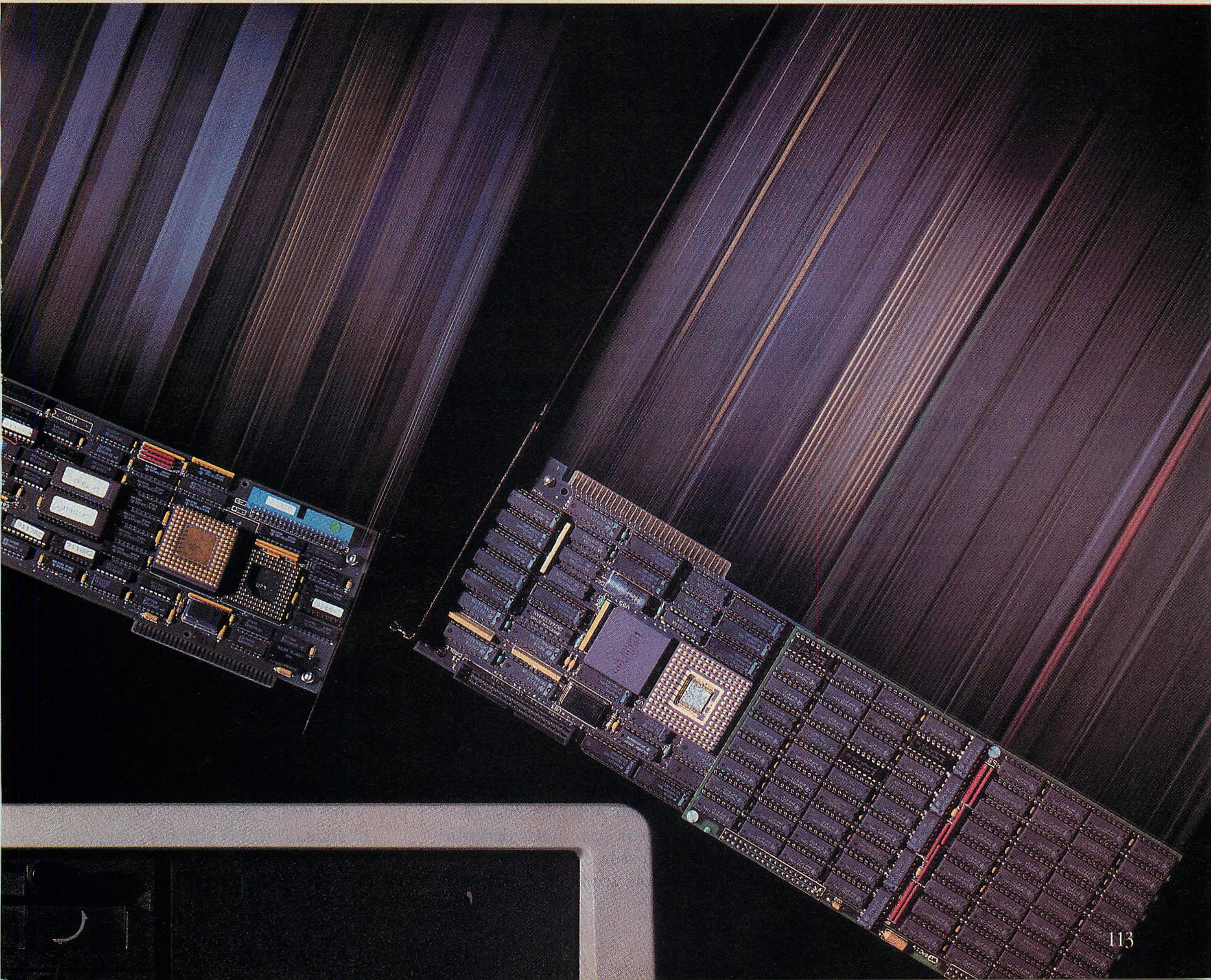

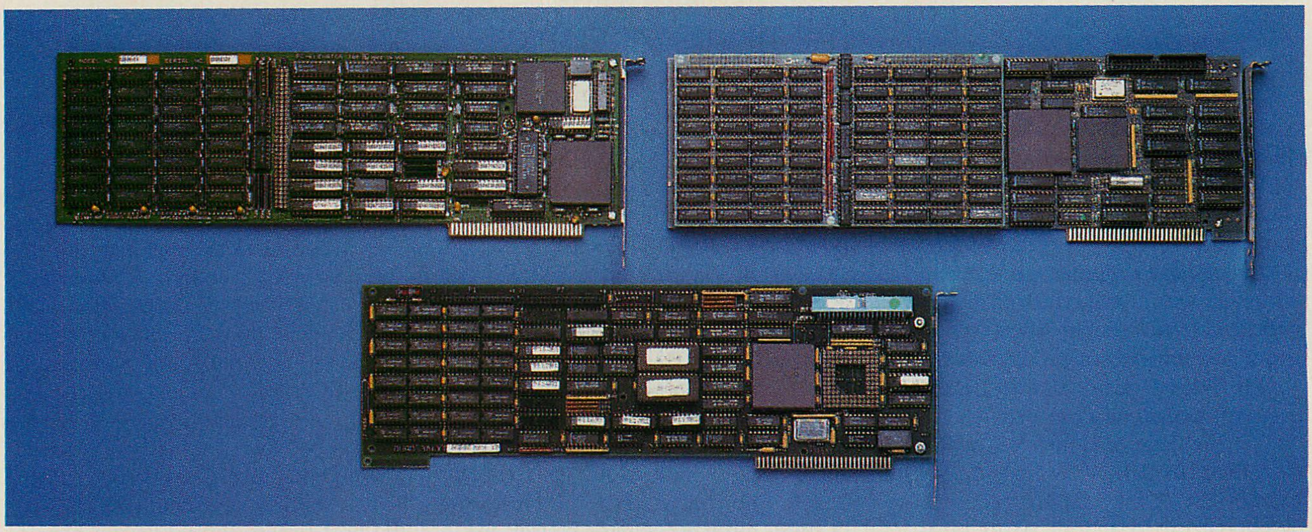

Applied Reasoning Corporation's PC-Elevator 386 is pictured at top left, Intel Corporation's Inboard 386/PC is at top right, and Quadram Corporation's Quad 386XT is at bottom center. The features common to all three 386 accelerator boards are: 1MB of on-board RAM, an 80387 math coprocessor socket, and pin headers for memory expansion daughtercards.

tensions. XT systems or PCs with hard-disk upgrades generally have adequate power and the necessary BIOS.

Furthermore, the board requires a full-length I/O channel slot. If your system has an available slot, fine; if not, something has to go. Any system that is to be enhanced with an accelerator board is likely to have a diskette controller, hard-disk controller, display adapter, and multifunction board with memory and I/O ports. Many also have extra serial adapters, internal modems, mouse interfaces, and the like. If the host system is a five-slot PC, you may have to make some compromises, such as having an external switch to select between a modem and serial mouse. A combination hard-disk and diskette controller is another way to save a slot, but may cost a few hundred dollars.

NOT A TRUE 386 MACHINE

What can be expected of a 386 accelerator for a PC? Ideally, the board would transform its host into the equal of a native 386 system. Besides more raw speed, users might expect the other benefits of the 386 architecture, including support for protected-mode software (such as OS/2), 386-specific software (such as Windows/386), and support for DOS applications that use extended memory (such as many RAM disks and disk-caching programs). This ideal is not attained.

The accelerator boards do offer tremendous performance boosts, generally for less cost than for similar boards that upgrade ATs. For example, a ready-to-install Intel Inboard 386/AT lists for $1,895 and increases the machine's power two- or threefold. An Inboard 386/PC makes an upgraded PC the technological equal of an upgraded AT, increasing performance tenfold, at a list price of $995.

What's the catch? While the accelerators bring demonstrable speed improvements, the hope of running protected-mode operating environments such as OS/2 and Windows/386 is just that—a hope. None of these programs works today on any upgraded PC, XT, or compatible. The reason is that operating systems need to know the specifics of certain hardware, such as disk, interrupt, and direct memory access (DMA) controllers, in order to manage them in a multitasking environment. BIOS does not support multitasking, so modern operating environments must access the hardware directly.

Current releases of OS/2 expect hard-disk, diskette, interrupt, and DMA controllers to be configured as they are in an AT. New drivers for the corresponding PC hardware need to be written before OS/2 can function in a PC or XT. All three vendors state that nothing in their hardware is incompatible with OS/2, but booting OS/2 requires a 1.2MB diskette as drive A:. Upgrading a system with both a 386 add-in board and a high-density drive and controller could cost as much or more than buying an OS/2-capable AT compatible. Therefore, vendors have little incentive to write the needed drivers and users have little hope of running OS/2 in a PC chassis in the foreseeable future.

The situation is more promising with Windows/386. Although this operating environment has similar dependencies on the hardware configuration, all three vendors are pursuing the adaptation of Windows/386 to their products. However, none is committing to a specific timetable.

At present, the only operating environment that takes advantage of features of the 386 and runs on these boards is Quarterdeck's DESQview 2.0.

DESIGN DIFFERENCES

Several features distinguish the three accelerator boards from each other and from similar boards for AT systems (see "Accelerating to the 386," Kent Quirk, January 1988, p. 108). A major architectural difference is in the design of a second processor that can be added to the system—either as a coprocessor that works with the original processor intact or as an emulator that replaces the original processor. The PC-Elevator 386 is a coprocessor design and both the Inboard 386/PC and Quad 386XT are emulator designs.

The PC-Elevator 386 coprocessor design connects to the system unit only through the I/O channel. Such devices cannot directly access anything on the system board, such as RAM memory, DMA and interrupt controllers, or the system timer.

Physically, the coprocessor board is a self-contained system with a 386 CPU, 32-bit memory, and a socket for a math coprocessor. The 386 and main 8088 processor can operate simultaneously, with the 386 passing requests for I/O or other services to the 8088 through I/O ports and shared memory. The 8088 performs the operation and passes the results back to the 386.

In addition to I/O channel connections, the Inboard 386/PC and Quad 386XT emulators use a ribbon cable to

attach to the 8088's socket. In this design, logic on the accelerator board mimics the signals of the 8088, giving the board direct access to all I/O devices and memory on the system board and in the I/O channel.

The coprocessor approach of the PC-Elevator 386 has some attractive properties. The system-board CPU can completely disable the coprocessor board, thus providing a fall-back position that allows the system to run in a totally compatible mode. Because the coprocessor CPU and memory are independent of the host system, the hardware design can be more straightforward, and the designers have more flexibility in arranging the 386 system components. The ARC board uses a four-way interleaved memory, which gives it significantly better performance in compute-intensive programs.

The primary disadvantage of the coprocessor is that true compatibility is harder to achieve because so much of the I/O has to be emulated in software. Many DOS programs expect to do their own I/O directly, either to improve performance or to perform functions not available in BIOS or DOS. The coprocessor must intercept all direct I/O operations and turn them into requests to the host CPU for service.

While each accelerator has 1MB of 32-bit RAM on board (with provisions for expansion), each one has a unique memory architecture. The 8088 in the PC and XT can address only 1MB of memory, and the system bus has no provision for addressing memory beyond 1MB. The 286 and 386, on the other hand, can address up to 16MB, but only when operating in protected mode; in real mode, they address only 1MB. The first megabyte is called conventional memory; memory beyond that is extended memory.

In the AT, the I/O channel provides the CPU and DMA access to all 16MB of conventional and extended memory. In real mode, BIOS functions (accessed by interrupt 15H) move blocks of data between conventional and extended memory and switch into protected mode.

Any 386 accelerator board for the PC has the interesting challenge of supporting extended memory in a system full of components that have no possibility of dealing with more than the first megabyte. How can a disk controller read and write to places it cannot even imagine?

The problem *can* be solved, thanks to the 386's ability to map any portion of the logical address space

TABLE 1: ***386 Accelerator Board Features***

	ARC	INTEL	QUADRAM
Model	PC-Elevator 386	Inboard 386/PC	Quad 386XT
Price	$1,795	$995	$995
Type	Coprocessor	Emulator	Emulator
Clock speed (MHz)	16	16	16
Standard memory (MB)	1	1	1
Memory chip rating (ns)	100	120	120
Expansion modules (MB)	2, 4	2	2, 8
Maximum memory (MB)	13	3	9
Math coprocessor	80387	80387	80387, Weitek 1167

Emulator design requires removing the 8088 from the system board and connecting a cable to the vacated socket; the coprocessor board coexists with the original CPU and communicates with the system only through an expansion slot.

into any piece of physical memory. This mapping is possible only in protected mode, however, so the solution must also use the virtual-86 mode of operation, which combines protected-mode memory mapping with compatible execution of programs (such as DOS and DOS applications) written according to real-mode rules.

All three accelerators provide software drivers that operate the processor in virtual-86 mode. The drivers map conventional and extended memory; optionally copy system BIOS, BASIC, and adapter BIOS ROMs to fast memory; and provide services from the Lotus-Intel-Microsoft expanded memory specification (EMS). The drivers also provide virtual DMA to the entire extended memory space. I/O and DMA operations involving extended memory are redirected to conventional memory, and then the results are copied to extended memory.

COMPATIBLE PERFORMANCE

Any change to a computer risks creating, or revealing, a compatibility problem. Tests of all software and hardware combinations would be definitive, but are impractical. Instead, several popular applications and utilities were tested on a five-slot PC, specifically those that perform direct I/O, handle interrupts, and use DMA and extended and expanded memory.

WordPerfect Corporation's WordPerfect 4.2 and the WordPerfect Library shell were used; both write directly to video memory and use expanded memory. Ready!, an outline processor from Living Videotext, is a memory-resident program activated by a hot key. Ready! will load itself into expanded memory if sufficient space is present, occupying only 3KB of conventional memory. PrintQ, from Software Directions Inc., is a memory-resident print-spooling program that uses hot keys and the DOS multiplex interrupt and performs disk file I/O. Quarterdeck's DESQview is an operating environment that provides windowing and multitasking of standard DOS applications; version 2.0 does not use virtual-86 mode, but it does use the 386's memory-paging mechanism to swap memory regions. Fastback Plus, from Fifth Generation Systems Inc., is a disk backup and restore utility that uses DMA for high-speed transfers between diskette and memory and performs direct I/O to the diskette controller.

A speeding 386 poses several potential sources of compatibility trouble. The most obvious are timing dependencies. Other problems can occur in virtual-86 mode, which is not *exactly* the same as real mode. In particular, the paging and protection features of the 386 are in force in virtual-86 mode, so privileged instructions (such as Halt) and illegal memory references can cause protection errors.

Details about the results of the compatibility tests are discussed below in the sections on the individual products. As expected, the tested programs had varying degrees of success. The Intel Inboard 386/PC had no problems, the Quadram Quad 386XT had just a few, and the ARC PC-Elevator 386 had the most. Programs that remain resident or perform complex system-level operations are the most likely to fail in an enhanced system, while well-behaved programs that obey operating system rules run with no difficulties.

The performance of the three products was tested with a combination of simple programs and selected *PC Tech Journal* performance benchmarks.

The performance results are listed in table 2. The first test used the DOS SORT utility to sort a file consisting of 4,000 random numbers. Both the input and output files were kept on a DOS 3.2 VDISK volume.

The Dhrystone test, with its mix of integer-arithmetic, decision-making, control-transfer, and parameter-passing operations, simulates a typical program. The version used is the one shipped with the Quad 386XT, written in Microsoft C 5.0 with full optimization. The times are for 50,000 iterations.

ATFLOAT measures the performance of floating-point operations. It was run both with and without math coprocessors. The coprocessors were an 8087 in the XT, an 80287 in the AT, and a 16-MHz 80387 on each board.

LOWLOOP is a simple assembly-language program that repeatedly copies each byte in the first 64KB of memory into itself. The object here was to see if performance in the first block of memory differed significantly among the boards. Speed differences were in line with that shown by other tests.

BASIC COUNT is an interpreted BASIC program that counts to 20,000. Its purpose was to see the effect of mapping the BASIC ROM into 32-bit memory. It also served as a general performance comparison.

Finally, selected measurements were made using both ATPERF and BUSPERF, part of the *PC Tech Journal* compatibility and performance suite. ATPERF measures processor and memory performance; BUSPERF determines the relative bus bandwidth.

In real-world programs, the accelerator boards speed up an XT by a factor of 6 to 8, depending on the mix of computation and disk access. The result is a machine that is significantly faster than an AT, especially in compute-intensive applications.

While all three accelerators operate at 16 MHz, each has significant differences in performance, primarily because of differences in the memory subsystems. The PC-Elevator 386, with its four-way memory interleaving, outperformed the others in most tests. The results for the Intel and Quadram products are quite similar, with the Quad 386XT slightly faster in most cases because of lower refresh overhead.

Intel sacrifices some performance in the name of compatibility, adding more wait states on certain I/O and BIOS operations to avoid timing problems. The IBM PC BIOS routines for serial communications, for example, do not work reliably in 6- or 8-MHz 286 machines because they do not allow enough time between I/O accesses to the 8250 serial controller.

TABLE 2: ***386 Accelerator Board Performance***

	IBM		ARC	INTEL	QUADRAM
PRODUCT	PC/XT	AT 339	PC-Elevator	Inboard 386/PC	Quad 386XT
PROGRAM TIMINGS (sec.)					
DOS SORT	395	100	42	56	52
Dhrystone	106	25	9	12	12
ATFLOAT (with *xx*87)	164	90	16	16	17
ATFLOAT (no *xx*87)	2,632	580	295	454	390
LOWLOOP	223	56	21	26	25
BASIC COUNT	74	21	7	14	11
ATPERF[a]					
Memory access (μs)					
Word fetch	1.83	0.40	0.16	0.14	0.13
Dword RAM read	N/A	N/A	0.14	0.27	0.25
Dword RAM write	N/A	N/A	0.21	0.27	0.25
Word ROM read	N/A	0.40	26.80	0.27	0.44
Byte video write	N/A	1.21	24.23	2.27	2.32
Wait states					
RAM read	N/A	1	0	2	2
RAM write	N/A	1	1	2	2
ROM read	N/A	1	420	2	5
Video write	N/A	8	380	34	35
CPU clock rate (MHz)	4.77	8.0	16.0	16.0	16.0
BUSPERF					
Bus bandwidth ratio	1.0	4.3	13.4	13.4	14.3

N/A = Not available

[a] *For the 8088 processor, ATPERF measures only word fetch time and clock rate.*

Installing an 80386 accelerator in a PC improves its overall performance by a factor of 6 to 10, to a level exceeding that of an AT. The ARC PC-Elevator 386 provides the highest speed increase, but also has the greatest compatibility problems.

The Quad 386XT contains a complete replacement BIOS, which Quadram claims avoids such timing problems. It is derived from the BIOS in the Datavue Portable PC. The Intel approach is more conservative and would seem to offer protection for any programs doing I/O directly to devices, not only through BIOS. Quadram's approach gives slightly better performance, but it risks problems with programs that avoid BIOS and deal directly with the hardware.

Applied Reasoning Corporation. The coprocessor design of ARC's PC-Elevator 386 makes it installable in more systems than the other two. It can be used in either XT or AT systems ("Accelerating to the 386" included a review of the PC-Elevator 386 as used in an AT). It is the only one reviewed that can be used in 8086 systems.

The standard configuration includes 1MB of 32-bit RAM; pin headers are provided for attaching daughtercards with more memory. Expansion modules are available with 2MB of RAM, and 4MB units are promised. Up to three such modules can be attached to the main board, for a total of 13MB of 32-bit memory. The daughtercards do not need to be plugged into expansion slots, but after the first one, they begin encroaching on the space above the adjacent slot, allowing it to accept short boards only.

The PC-Elevator 386 is packaged with one 5.25-inch diskette and a well-written user's manual that clearly explains the installation, setup, and operation of the system.

This board is the easiest accelerator to install because it simply plugs into an available I/O channel slot. The host system processor must remain on board; the coprocessor design requires the host processor to perform actual I/O operations to devices not located on the coprocessor board.

With a menu-driven setup program, the user describes the system hardware configuration and selects the amount of memory to be used for a disk cache and conventional, extended, and emulated expanded memory, then produces a customized device driver for the 386, or "upstairs" processor.

This driver provides virtual-86 mode kernel services, expanded memory emulation, and disk-caching support.

Four DIP switches determine the I/O and memory addresses the board occupies in the host system. As many as four PC-Elevator 386 boards can be present at once, although the drivers provided can deal with only one. The setup program scans the host system for possibly conflicting devices and memory and suggests the best DIP-switch configuration.

The coprocessor strategy leads to some confusion about just which processor is active. When the system starts up, the original host (or "downstairs" processor) is in control. The UP program, which executes in the downstairs processor, starts the 386 and waits for I/O requests from upstairs. Meanwhile the upstairs processor is running, booting DOS again, and loading the device driver, which provides virtual-86 mode support and EMS 3.2 emulation.

The confusion arises because two different copies of DOS are running at the same time against the same disks, each with its own idea of current directory, disk buffers, and so forth. A user can easily forget which processor is attached to the keyboard and display.

The upstairs driver emulates EMS from extended memory and can include any manufacturer's physical EMS board and driver in the total EMS pool. Ordinarily, a system can have only one extended memory manager (EMM) driver, and because each manufacturer's paging hardware is slightly different, the driver must match the memory board. In the PC-Elevator 386, the upstairs CPU simply passes EMS requests to the downstairs CPU whenever it needs more expanded memory than its own emulation can provide. The downstairs processor then calls its own EMM driver to handle the request, and the results are sent back upstairs.

The PC-Elevator 386 exhibited some serious compatibility problems with several of the software packages. Ready! worked fine in the downstairs processor, but once activated in the upstairs processor, it refused to quit. With the upstairs EMM driver installed, Ready! would not even load properly. The system gives an "Attempt to DMA to illegal memory address" error message and kicks you back downstairs.

The installation procedure for Fastback Plus performs some DMA tests to determine the best speed for operation. Fastback reported the low-speed DMA test passed and then announced the start of the medium-speed DMA test. It then hung before announcing the result of the test, requiring a reboot. On the second attempt, the DMA test caused the upstairs kernel to generate an error message indicating an unexpected general protection fault on an I/O instruction, and it switched control back downstairs. Attempting to go back UP then resulted in a "Parity Check 1 10000 (S)" message, after which a power-off/on cycle was required to restart the system.

Intel Corporation. The Inboard 386/PC comes with an installation manual, the emulator board, a cable for connecting to the 8088-processor socket, a diskette, a tool for prying out the existing 8088 and 8087 chips, and two plastic tubes (Intel insiders call them "chip coffins") thoughtfully provided to house the displaced processors. The on-board RAM complement of 1MB can be expanded by adding one 2MB expansion module.

The installation manual is detailed, well-illustrated, and reasonably foolproof. It contains different sets of instructions for machines from IBM, Compaq, and Tandy. It is important to be careful when removing the processor chips to avoid damaging the system board. Inserting the cable connector in the 8088 socket can be a little tricky.

Intel provides an automatic setup program that copies files from the diskette to the hard disk and modifies the CONFIG.SYS and AUTOEXEC.BAT files as required by the options selected. It is mildly annoying that the setup program only adds lines to CONFIG.SYS and AUTOEXEC.BAT; it does not modify or delete existing lines if you run it again to change the setup. It is best to follow the manual installation procedures to set the desired driver options on subsequent setups.

Running the setup program or installing any of the software is not necessary for the Inboard 386/PC to function. The board runs by default in real mode at full speed, but without access to extended memory or the ability to map the slow ROMs into 32-bit RAM.

The hardware installation instructions call for disabling or removing the system's existing conventional memory, because the Inboard 386/PC provides 640KB of conventional memory. Of the remaining memory, 128KB is reserved for mapping 8-bit ROMs, and 256KB is for extended memory. On power-up, if the board detects conflicting conventional memory, it beeps S-O-S in Morse code to indicate a setup error.

The INBRDPC.SYS driver implements the virtual-86 mode kernel, which supports extended memory func-

tions (via interrupt 15H), ROM mapping to fast memory, and a speed-control feature using Ctrl-Alt-Shift and 1 (slowest) through 4 (fastest). The slower speeds add more wait states to memory and bus cycles. The speed control is also available from the ISPEEDPC.EXE command.

The ILIM386.SYS driver uses the 386-mapping facilities to emulate expanded memory using extended memory. ILIM386 implements EMS 4.0. Unfortunately, the user must choose between physical expanded memory (such as on an Above Board) and the emulated EMS. Intel recommends keeping existing EMS boards and using the drivers that come with them. The performance using these boards will not be as good as with the emulated EMS, but the investment in the EMS board is protected. As a convenience to Above Board owners, the latest Intel Above Board EMS 4.0 driver is included on the Inboard 386/PC software disk.

Software provided with the Inboard 386/PC includes a disk cache, utilities to display the current driver parameters and memory allocation settings, and a program that reinstalls the speed-control software in the event that the system has ill-behaved resident programs that steal the keyboard interrupt vector without properly chaining to the previous interrupt handler.

The Inboard 386/PC exhibited no compatibility problems with any of the software tested. For added insurance against speed-related problems, the INBRDPC driver has options that allow independent selection of the number of wait states (from 0 to 30) added to diskette operations, hard-disk operations, or all memory cycles.

Quadram Corporation. The Quad 386XT kit consists of the board, operations manual, software diskette, connecting cable for the 8088 socket, a module that plugs into the 8087 socket, and an *L*-shaped chip extraction aid. Like the other two boards, this one comes standard with 1MB of memory. A daughtercard with 2MB is available; an 8MB expansion is planned (its price is as yet unannounced).

The manual, written for Quadram by an outside company, is generally adequate, but has an annoying stylistic quirk that uses quotations around perfectly "normal" words to indicate that a "simple" word is used in place of a more "technical" one.

The manual's "Programming Considerations" section provides information about the control registers on the Quad 386XT, switching between real and virtual-86 modes, and the interrupt 15H services provided by the on-board BIOS. These are a subset of the services provided in an AT-class BIOS for determining the size of extended memory, block moves, and getting system environment information.

The Quad 386XT is installed very much like the Intel board, with the added step of plugging the 8087 adapter module into the 8087 socket on the system board. The Quad 386XT has an oversized pin-grid array socket that can accept either an 80387 math coprocessor chip or a Weitek coprocessor module. The installation instructions for the coprocessor are rather elaborate: insert coprocessor, install board, run diagnostic test that fails if coprocessor is installed, remove coprocessor, run diagnostic to prove it is not there, reinstall coprocessor.

The Quad 386XT has no automatic installation software; the user just adds the necessary lines to CONFIG.SYS and AUTOEXEC.BAT. The manual describes the options very well. The workhorse of the Quadram software is QVM.SYS,

which stands for Quadram Virtual Monitor. The QVM driver is a virtual-86 mode monitor that controls extended memory, BIOS and adapter ROM mapping, and expanded memory emulation. A companion program, QVM.COM, allows switching between virtual-86 and real modes.

Another driver, DDINT10.SYS, speeds up video operations by replacing portions of the video BIOS with more optimized code. The driver works fine, but produces lots of snow and flickering on a CGA.

In addition to the Dhrystone benchmark, the Quadram software includes a diagnostic program, utilities for RAM disks (conventional, extended, and expanded memory versions), and four print spoolers (for all combinations of serial/parallel ports and conventional/expanded memory).

The memory on the Quad 386XT is physically addressed starting at 1MB, the beginning of the extended memory range. The QVM driver software normally runs in virtual-86 mode and remaps the system's conventional memory above the 32-bit memory, where it emulates EMS 3.2 memory or provides slow extended memory. Thus, the total system memory is 1MB more than the amount the host PC had originally.

The QVM utility toggles operation between real and virtual-86 mode. Of course, real mode can use only the 8-bit host-system memory, and the resulting operation is slightly slower than the unenhanced 8088 system. The software-controlled switching is convenient for dropping the processor speed back to its original value to get past some copy-protection mechanisms or to run software that generates protection errors in virtual mode.

A serious deficiency of Quadram's current software is its inability to map on-board memory to backfill the DOS area to a full 640KB. With the current setup, DOS is limited to the amount of conventional 8-bit memory physically installed in the system, even though that memory is mapped out of the way and DOS actually runs in fast extended memory. That means either taking up another slot for a memory expansion board, or, if no slot is available, restricting DOS to only 64KB or 256KB, which is not at all practical.

Quadram's EMM driver knows how to address Intel Above Boards and Quadram EMS boards, and it can combine the physical expanded memory the emulated expanded memory into a single pool.

Concerning compatibility, Quadram warns that Norton's SYSINFO utility can hang the system if BIOS is mapped to 32-bit RAM, and that some hard-disk controllers have on-board BIOS code that is timing-sensitive and will not work with the Quad 386XT. The Norton problem can be avoided by simply not mapping BIOS to RAM. Quadram's technical support staff will assist customers who need a replacement BIOS for their disk controllers.

A more serious compatibility problem showed up when using WordPerfect from within the WordPerfect Library menu system. WordPerfect 4.2 would not return to the WordPerfect shell; the action key caused a return to the word processor instead of to the menu shell. WordPerfect without the shell was able to go to DOS and back again without any problem.

NEW MIPS FOR OLD

Of the three products, the ARC PC-Elevator 386 is by far the fastest, the most expensive ($1,795), and the most plagued by compatibility problems. Video performance on a CGA display, however, was dismally slow and snowy. The compatibility problems make it a risky choice for general-purpose DOS use. The PC-Elevator 386 is priced to compete with accelerators for AT-class machines, not with the other two products. Its coprocessor architecture, which allows several units to operate simultaneously within a single host system, gives the PC-Elevator 386 some interesting possibilities for OEMs and developers of custom applications.

The Quadram Quad 386XT performed second-best, costs only $995, and showed at least one compatibility problem with WordPerfect. Its current inability to backfill conventional DOS memory to 640KB is a serious drawback, especially in PC-1 systems with 64KB system boards and only five I/O channel slots. If Quadram would modify its driver software to support backfilling, then its ability to combine existing 8-bit conventional and expanded memory with the on-board 32-bit extended memory would provide the most flexible memory configuration options of all. The Quad 386XT's performance and ability to accept a Weitek module might tip the balance in its favor for users with a need for very fast floating-point processing.

The Intel Inboard 386/PC ($995) was the only board that experienced no compatibility problems. Its performance is only slightly slower than the Quadram board. Intel chose to divide the 1MB of memory to provide the full 640KB of conventional DOS memory, 128KB for BIOS remapping, and 256KB of extended memory. This is a better choice for PC systems with limited room for 8-bit conventional memory. Systems requiring large amounts of expanded memory can use dedicated EMS boards instead of the EMS emulator software. Intel covers the Inboard 386/PC with a five-year warranty, compared with the one-year warranties that ARC and Quadram offer.

These 386 add-in boards for the PC are the ultimate in accelerators, offering reasonably cost-effective ways of upgrading system performance while preserving much of the existing investment in hardware and software. They should not, however, be expected to do more than provide an increase in raw computing speed.

A PC with one of these products is a far cry from a full 386 machine, with no immediate prospects of running protected-mode software, such as OS/2, Windows/386, PC-MOS/386, or UNIX. Whether any of this software will be adapted for these boards is still unclear. Therefore, these products are recommended only for those who need a fast PC and can accept the fact that it essentially remains a PC.

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Thomas V. Hoffmann, a consulting editor for PC Tech Journal, is manager of systems development at RoadNet Technologies Inc., located in Baltimore, Maryland.

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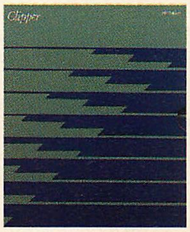

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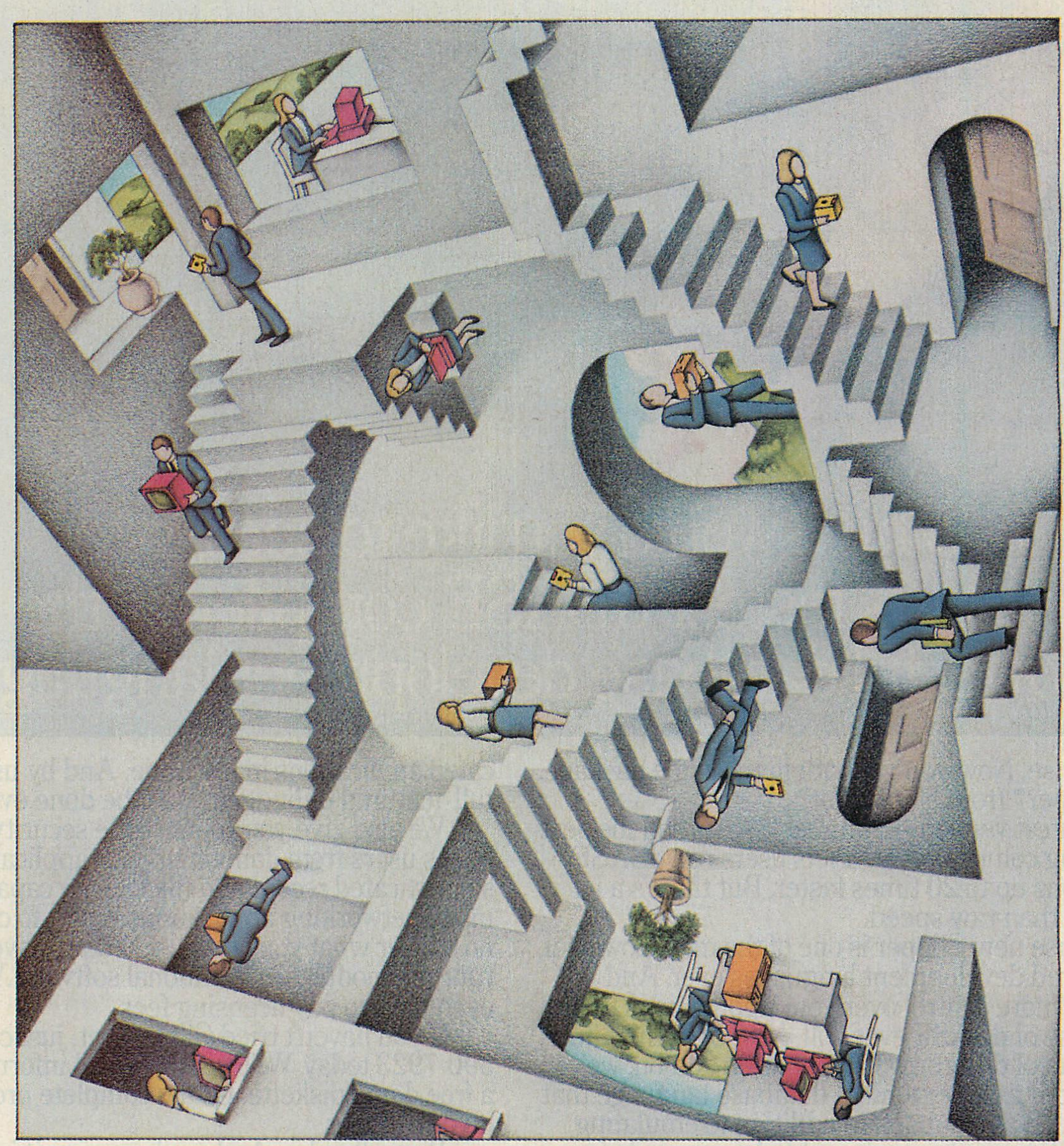


Family Ties

The answer to the dilemma—DOS or OS/2?—may be family mode. Applications developed in family mode can run unchanged under either operating system. Of course, there are sacrifices.

DAVID A. SCHMITT

IBM and Microsoft, codevelopers of OS/2, are building bridges between the old world of DOS and the new world of OS/2. One such bridge is through family mode—programs that can run unchanged under both OS/2 and DOS. The very term *family* mode conveys that OS/2 and DOS are members of a compatible operating-system *family*.

The same family-mode .EXE file can run in OS/2 protected mode, OS/2 real mode, and under DOS. When a family-mode application is running in protected mode, it enjoys the primary benefits of OS/2—access to more than 640KB of memory and the ability to run simultaneously with other protected-mode applications. Family-mode applications cannot freely use advanced OS/2 features, such as internal multithreading or interprogram communications, because these are not available under DOS.

For software developers, family-mode applications offer the advantages of learning and using OS/2 without abandoning DOS compatibility. Family mode gives developers an alternative when faced with the either-or decision of designing OS/2 protected-mode applications or continuing to write DOS applications while waiting for an 80386-specific operating system.

Family-mode applications are valuable in aiding acceptance of OS/2 and easing transition to the new operating system. OS/2's popularity depends largely on software developers running with the family-mode concept and making available significant protected-mode applications.

This is particularly true given that OS/2 can handle only one DOS program at a time while some DOS extensions and alternative operating systems handle more than one, satisfying user needs to multitask existing DOS programs (see "Choosing an Operating System," and "386 Operating Environments," Ed McNierney, January 1988, p. 50 and p. 60, respectively). Unlike OS/3 of the future, which will exploit the power of

PHOTOGRAPHY • DON CARSTENS


OS/2
DOS

80386-based computers and provide multiple DOS partitions, OS/2 allows running only one DOS program at a time and in a smaller partition than under native DOS.

Two OS/2 features that support family mode are the application program interface (API) based on function calls and dynamic linking (see "An Architecture for the Future," Martin Heller and "The Flexible Interface," David A. Schmitt, November 1987, p. 66 and p. 110, respectively). OS/2 family-mode functions are shown in table 1.

A family-mode application uses only OS/2 API features that have counterparts under DOS. The OS/2 Programmer's Toolkit contains a library named API.LIB that has DOS versions of many OS/2 API services. Functions in API.LIB are called according to conventions of the OS/2 API, but they generate software interrupts corresponding to DOS and BIOS services. By using API services and programming techniques that are common to both operating systems, family-mode applications can shield the user from knowing under which operating system a program is running.

To construct a family-mode application, a developer first compiles and links it for OS/2, using that operating system's standard build tools. Linking in this case means inserting references to the API routines in a dynamic link library (DLL). When the application is loaded for execution under OS/2, the loader resolves the references and then reads in the required API routines from the DLL.

An OS/2 application is converted to a family-mode application by processing the .EXE file with the Bind utility that is provided with the toolkit. The Bind utility adds a stub loader and the necessary API.LIB routines to the .EXE file, but unlike a static linker, it does not resolve API calls, which would defeat dynamic linking and prevent the file from executing in protected mode.

The dual-mode capability of the family-mode program is due to the fact that API calls are not resolved until load time. If loading occurs in protected mode, the OS/2 program loader resolves these calls to OS/2 service routines in a DLL; in real mode, the stub loader performs this function, resolving the same calls to DOS interface routines from API.LIB.

In protected mode, both the loader and the DLL are parts of OS/2; the loader loads only the original portion of the .EXE file, ignoring portions added by Bind. The program loader resolves all calls to OS/2 API functions via the dynamic linking facility.

The presence of the loader and API routines in the .EXE file makes the program self-sufficient for execution in real mode. Whether under DOS or in the compatibility box of OS/2, the program loader reads the stub loader and the API.LIB functions into memory together with the rest of the program. The stub loader gets control, relocates the OS/2 API function calls to point to the API.LIB routines, and then passes control to the application program. From that point on, the application's calls to the OS/2 API are translated into the equivalent DOS services by the API.LIB functions.

TABLE 1: *OS/2 Family-Mode Functions*

SYSTEM/FILE		
DosAllocHuge	DosFreeSeg	DosQFSInfo
DosAllocSeg	DosGetCollate	DosQVerify
DosBeep	DosGetCtryInfo	DosRead
DosCaseMap	DosGetDateTime	DosReallocHuge
DosChDir	DosGetEnv	DosReallocSeg
DosChgFilePtr	DosGetHugeShift	DosRmDir
DosCLIAcess	DosGetMachineMode	DosScanEnv
DosClose	DosGetMessage	DosSearchPath
DosCreateCSAlias	DosGetVersion	DosSelectDisk
DosCWait	DosHoldSignal	DosSetDateTime
DosDelete	DosInsMessage	DosSetFHAndState
DosDevConfig	DosMkDir	DosSetFileInfo
DosDevIOCtl	DosMove	DosSetFileMode
DosDupHandle	DosNewSize	DosSetFsInfo
DosErrClass	DosOpen	DosSetSigHandler
DosError	DosPortAccess	DosSetVec
DosExecPgm	DosPutMessage	DosSetVerify
DosExit	DosQCurDir	DosSubAlloc
DosFileLocks	DosQCurDisk	DosSubFree
DosFindClose	DosQFHandState	DosSubSet
DosFindFirst	DosQFileInfo	DosWrite
DosFindNext	DosQFileMode	
KEYBOARD		
KbdCharIn	KbdGetStatus	KbdSetStatus
KbdFlushBuffer	KbdPeek	KbdStringIn
VIDEO I/O		
VioGetBuf	VioScrollLf	VioWrtCharStr
VioGetCurPos	VioScrollRt	VioWrtCharStrAttr
VioGetCurType	VioScrollUp	VioWrtNAttr
VioGetMode	VioSetCurPos	VioWrtNCell
VioGetPhysBuf	VioSetCurType	VioWrtNChar
VioReadCellStr	VioSetMode	VioWrtTTY
VioReadCharStr	VioShowBuf	
VioScrollDn	VioWrtCellStr	

The subset of OS/2 API functions that is available to a family-mode application consists of those services that have counterparts in DOS or BIOS. The real-mode routines that implement these functions are bound into the family-mode .EXE file, but they are replaced at runtime by dynamically linked OS/2 versions if the program runs in protected mode. Descriptions of these functions are provided in table 3 in "The Flexible Interface," David A. Schmitt, November 1987, p. 110.

UNDERLYING SUPPORT

Key to the workings of family mode is the structure of the OS/2 .EXE file and the way the Bind utility transforms the executable file produced by the protected-mode linker. To support new OS/2 features, such as segment protection and dynamic linking, the format of an .EXE file is expanded from the relatively simple DOS structure.

Figure 1 shows major sections of an OS/2 executable file. The file has three sections recognized by DOS: the header, relocation table, and DOS stub program. OS/2 sections begin with a header and end with a section for each OS/2 code or data segment. Intermediate sections contain information about

program-required segments, dynamic links, and other resources.

As far as DOS is concerned, an OS/2 .EXE file consists of only the components before the OS/2 header. Any attempt to execute an OS/2 program in real mode causes DOS to load only the stub program, which displays a message indicating that the program can be run only in protected mode. As another option, the DOS-formatted header can specify a fictitiously large memory requirement, so the loader does not even attempt to load the stub. The protected-mode loader gets the true memory requirement from the OS/2 header farther down the file, ignoring most of the DOS-formatted information.

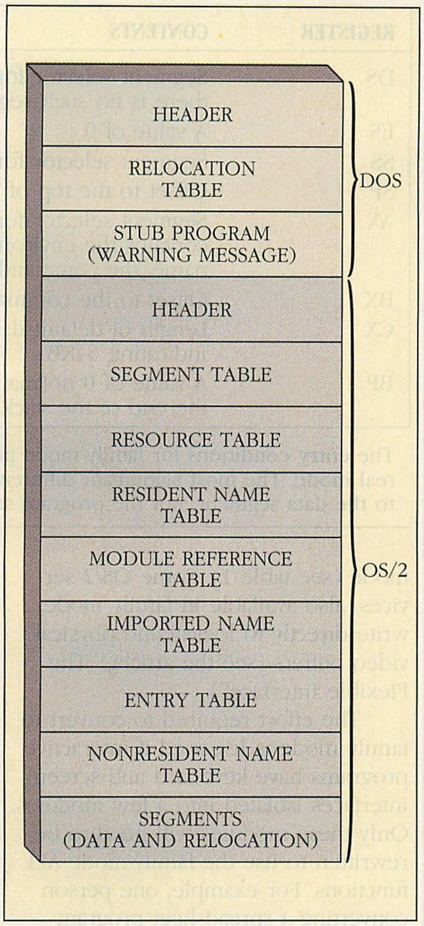
Figure 2 shows the structure of a family-mode .EXE file that the Bind utility produces from the protected-mode .EXE file. Its major components are similar to those in figure 1, except that the small DOS stub that displays the warning message is replaced with a much larger section containing the stub loader, the functions extracted from API.LIB, plus any object modules explicitly mentioned in the Bind command. All OS/2 sections remain unchanged and are simply moved upward in the .EXE file to accommodate the expanded DOS section.

When the program executes in real mode, the operating system loader reads in only DOS-formatted sections and passes control to the DOS stub program. Instead of displaying an error message as the default stub did, the one supplied by Bind reopens the .EXE file, loads the OS/2 code and data segments, links OS/2 service calls and the functions from API.LIB, sets machine registers to the OS/2 entry conditions (see table 2), and then jumps to the main entry point of the OS/2 program that is fully set up to run under OS/2.

Details about processing protected-mode .EXE information and DOS memory allocation make the stub loader a little bulky. The .EXE file for a small sample application called FAMDEMO.ASM (listing 1) grows from 1,116 bytes to 9,308 bytes, a factor of more than eight, after Bind processes it. The increase is not proportional to the original .EXE size. For example, the .EXE file of a moderately sized real application increased from 127KB to 154KB after binding, an increase of only 22 percent.

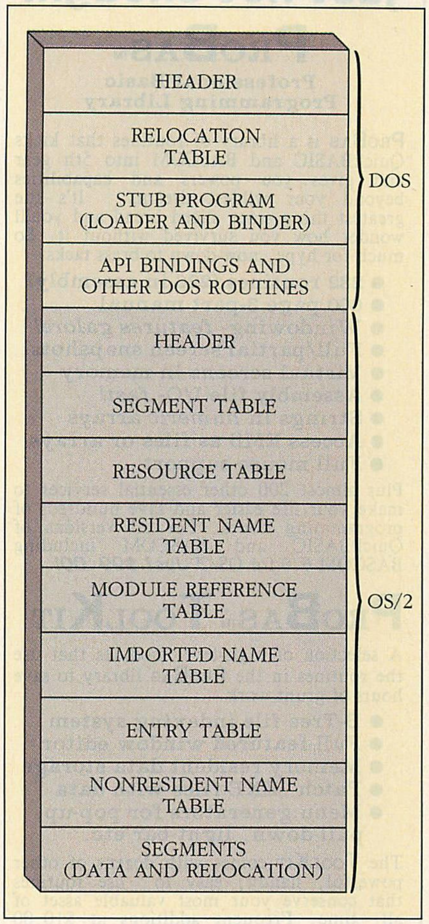
Performance of family-mode programs is not an issue when loading or executing a program in protected mode because the OS/2 program loader ignores the real-mode portions

FIGURE 1: ***OS/2 .EXE File***



The file consists of two sections—one for DOS and one for OS/2. Each operating system ignores the other's section. The DOS stub program issues an error message and terminates.

FIGURE 2: ***Family-Mode***



The expanded DOS stub program performs functions of the OS/2 loader: it links API function calls to the bound routines, sets entry conditions, and branches to the OS/2 entry point.

of the file regardless of size. In real mode, loading is slightly slower, but DOS and OS/2 family versions of an application generally run at equivalent speeds. The routines in API.LIB are efficient. One disadvantage to family mode is the increase in memory required, because the API routines reside in the application's memory space.

FROM DOS TO FAMILY MODE

In this early phase of OS/2 deployment, most interest in family mode probably comes from those who want to adapt DOS programs to OS/2 without losing DOS compatibility. A single executable file that runs in any mode lowers production and maintenance costs and leaves users less confused.

If a DOS program is well-behaved, it can be adapted easily to family mode by recompiling it with the appropriate OS/2 compiler, linking it, and binding it to API.LIB. A well-behaved C program designed for DOS has these traits:

- It handles DOS interfaces through the compiler's standard library.
- It does not use low-level DOS interface functions from the library, such as **int86**, **intdos**, **bdos**, or **bios**.
- It does not hook into hardware or software interrupts.
- Keyboard and screen interactions use the simple glass-teletype approach or the ANSI.SYS driver for complex screen operations.
- It treats 32-bit pointers as atomic objects and does not separately manipulate segment and offset portions.

Some programs, for reasons of performance, deviate from these rules. In many cases, however, even they can be converted easily to family mode. For example, many screen-oriented programs write directly to the video display buffer or call the BIOS services instead of using DOS video services. Most of the OS/2 keyboard and video functions (with names beginning with Kbd and Vio) are available in family

TABLE 2: *Registers at Entry to OS/2 Programs*

REGISTER	CONTENTS
DS	Segment selector for the default data segment, or 0 if there is no such segment.
ES	A value of 0.
SS	Segment selector for the default stack segment.
SP	Offset to the top of the default stack.
AX	Segment selector for the environment segment, which contains the environment strings, the application file name, the command verb, and the residual command line.
BX	Offset to the command verb in the environment segment.
CX	Length of default data segment, with a value of 0 indicating 64KB.
BP	A value of 0 normally pushed onto the stack to indicate the end of the stack frame chain.

The entry conditions for family-mode programs are the same for OS/2, even in real mode. The most significant difference from DOS is that the DS register points to the data segment, not the program segment prefix (PSP).

mode (see table 1). Some OS/2 services, also available in family mode, write directly to logical and physical video buffers (see the article, "The Flexible Interface").

The effort required to convert to family mode is lessened if interactive programs have keyboard and screen interfaces isolated into a few modules. Only these modules will need to be rewritten to use the family-mode API functions. For example, one person converting a spreadsheet program (30,000 lines of C code) to family mode using this technique took one week to complete the task.

Determining if assembly language functions are well-behaved by visual inspection is more difficult than with C. Without a compiler to generate low-level code sequences, an assembly language programmer accidentally can use instructions that are not allowed in family mode. Developers should avoid the following common DOS coding practices that can cause problems in protected mode:

- Software interrupts (INT instructions)
- Direct access to I/O ports with IN and OUT instructions
- Changing the state of the interrupt enable flag with CLI and STI instructions
- Segment register arithmetic, such as the following sequence which advances to the next 64KB segment:

```
MOV AX,DS
ADD AX,1000H
MOV DS,AX
```

- Timing loops, such as:

```
MOV CX,1000
DELAY: LOOP DELAY
```

INT, IN, OUT, CLI, and STI instructions cause protection violations because OS/2 does not allow non-privileged processes to execute them. Segment register arithmetic often causes addressing exceptions because the process attempts to load an invalid selector into a segment register. Timing loops cause the program to behave erratically because the time delay might differ between real and protected mode, even on the same computer. Timing loops are ill-advised, even under DOS, because they might become invalid after upgrading to a faster computer.

BUILDING NEW APPLICATIONS

Designing new OS/2 applications that will remain compatible with DOS is a bigger challenge than converting existing DOS programs. To develop applications that will run the same in DOS and OS/2, developers should: use a high-level language (such as C); use whatever compiler options are necessary to generate only 8086 instruction sequences; use only library functions that restrict OS/2 API calls to family-mode services; and not rely on multitasking or access to more than 640KB of memory.

Note that limiting a program's system calls to the family API is not by itself sufficient to insure execution in family mode. For example, an OS/2 application could consist of two or more programs that expect to run simultaneously and exchange data via shared files accessed via standard file I/O calls, not the interprocess communication protocols. Even though each individual program uses nothing but family API calls, such an application

cannot be converted to family mode because it relies upon OS/2 multitasking for the concurrent execution of the several components.

To avoid breaking these rules, the safest way to create a new family-mode application is to develop it entirely under DOS, but using the family-mode OS/2 functions instead of the DOS API. This negates the possibility of hidden dependencies on new OS/2 features, such as larger-than-640KB memory. Once the program runs under DOS, getting it to run in protected mode should be easy.

Initially available OS/2 C compilers (from IBM, Lattice, and Microsoft) readily support family-mode programming in that they typically generate 8086 code as default, and most library functions use only family-mode API services. Functions that do not support family mode represent a small fraction of the library and generally are designed for real-mode-specific tasks, such as generating software interrupts or interfacing with the network manager. Even without this small proportion of functions, family-mode applications can use most of the functionality of a compiler's runtime support library.

Developers who want family applications that behave differently in real mode than in protected mode can embed instruction sequences to execute only under DOS and others to execute only under OS/2.

A spreadsheet program, for example, could use a simple calculation algorithm under DOS, where the size of the spreadsheet is constrained by the 640KB limit. In the OS/2 environment, where spreadsheets can get much larger than 640KB, it might be appropriate to create a separate thread that calculates in the background while the user continues to enter data via the main thread running in the foreground. This reduces keyboard delay during recalculations.

This method is easy to implement because nothing in either DOS or OS/2 prevents loading an .EXE file containing API calls and instruction sequences for the other mode, although the Bind utility detects any nonfamily API calls and issues warnings. If the program hits a real-mode instruction sequence under OS/2, such as a segment register arithmetic, the operating system aborts the program. It is not as clean under DOS, where a protected-mode instruction sequence can cause a system crash or produce garbled results.

DOS- and OS/2-specific sequences should be entered only after appropri-

ate mode tests. The simple C function that follows can be called to ask, "Is this OS/2 protected mode?"

```
extern far pascal
   DosGetMachineMode(char far *);
int isos2p();
{
      char mode;
      DosGetMachineMode
         ((char far *)(&mode));
      return((int)mode);
}
```

The **isos2p** function calls DosGetMachineMode, which is in the family API. The only argument to this API function is a pointer to a single byte, which is set to 0 for DOS and 1 for OS/2. A program can contain the following logic to tailor its operation to the processor mode:

```
if(isos2p())
{
      /* do OS/2 stuff */
}
else
{
        /* do DOS stuff */
}
```

The program needs to call DosGetMachineMode only once because an application cannot change modes after it is started. Most OS/2 C compilers determine the machine mode as part of their start-up procedures and place the mode value in a global variable accessible throughout the program. The mode can be more efficiently determined by testing this variable instead of calling a function each time. With compilers that do not automatically provide such a value, developers can call DosGetMachineMode once near the beginning of a program and place the result into a globally accessible variable.

SAMPLE APPLICATION

The sample application FAMDEMO.ASM (listing 1) prints a message that identifies the mode in which it is running; it then exits to the operating system. The three OS/2 API calls—VioWrtTTY, DosGetMachineMode, and DosExit—are in the family API repertoire. The entry conditions (see table 2) are those of OS/2, even in real mode. Therefore, the DS register at entry points to the data segment, not the program segment prefix (PSP), so the application does not need to establish addressability to the data. If the program needs access to the PSP, it can obtain the address with function 62H of interrupt 21H (after determining that real mode is in effect). The most common reason for accessing the PSP is to obtain the address of the environment, but in family mode the loader places this address into the AX register.

The following commands assemble, link, and bind the sample program:

```
masm famdemo;
link famdemo,,,doscalls;
bind famdemo doscalls.lib api.lib
```

The assembler can be any version that produces Microsoft-compatible object files, but the linker must be the OS/2 version. The **masm** command produces the object file, called FAMDEMO.OBJ, from which the linker produces the protected-mode executable FAMDEMO.EXE, using DOSCALLS.LIB (given as the fourth argument) to resolve calls to API functions. The functions themselves are not in this library file because the OS/2 API library is dynamically loaded at runtime. The semicolon after the library name indicates that no module definition file exists. This is a new OS/2 linker feature that gives developers a great deal of control over the structure of the .EXE file.

The first argument to the Bind command is the name of the .EXE file, followed by the names of the DLLs

TABLE 3: *Command-line Options for Bind Utility*

OPTION	DESCRIPTION
/O *newexe*	Names a new executable output file to be created instead of replacing the input .EXE file. An extension other than .EXE may be specified.
/M *mapfile*	Produces a symbol map file with default extension of .BM.
/N *func*	Binds the named function to the entry BadDynLink when the program runs under DOS. Instead of a function name, the argument can be *@file* to specify a file containing a list of such functions.

The presence of calls to API functions not defined in family mode normally causes Bind to generate unresolved reference errors. The /N option allows binding such references to the BadDynLink entry, which may be a custom-written procedure.

being used by the program. In the sample program, only one DLL is specified—DOSCALLS.LIB. The command line also must specify API.LIB, the DOS binding library that provides the actual DOS versions of the API functions. Although the .EXE extension on the input file can be defaulted, the .LIB extension must be explicitly stated for the library files. This is because the Bind utility can accept object files, with .OBJ extensions, that are to be bound into the new executable file.

DOSCALLS must be mentioned in both the Link and Bind commands because Link consults the library in order to convert each API name (such as DosExit) into a numeric index, which is called an ordinal reference. The names usually are not placed into the .EXE file, and the OS/2 loader finds the required functions in the load-time DLL using ordinal references. API.LIB, however, is not a DLL, and its members cannot be found by ordinal reference, but must be located by name. The Bind utility, therefore, must look in DOSCALLS.LIB to convert the ordinal references back to function names.

Use of the Bind command as shown causes the new family-mode .EXE file to overwrite the protected-mode input file. The Bind command has other useful options, as shown in table 3. The most interesting and helpful option is /N, which allows programs to handle calls to functions that do not have family-mode versions in API.LIB. When binding a program with such calls (for example, within conditional constructs), the Bind utility generates an unresolved reference message for every function that is not in API.LIB.

If the developer identifies those functions in the /N option, Bind resolves API references to a function named BadDynLink. The default version of this function supplied with API.LIB displays an error message and aborts the program. If a program error causes execution in real mode to fall into the protected-mode branch of a conditional, the program can end cleanly without crashing.

Developers can supply their own version of BadDynLink in an object module that they name in the Bind command line:

```
bind prog
  doscalls.lib
  badlink.obj
  api.lib
  /n DOSCREATETHREAD
```

This includes the object file BADLINK.OBJ, which must contain the customized definition of function BadDynLink, in the output .EXE file. If the program **prog** makes any calls to DosCreateThread (the function mentioned in the /N option) when running in real mode, the customized BadDynLink is called. Instead of ending the program, this BadDynLink could take some other action.

The Bind utility has one annoying shortcoming. Unlike the linker, Bind does not use an environment variable to locate libraries not in the current directory. It is most convenient to keep source and library files in different directories and build applications in the source directory while specifying the path to the libraries with the LIB variable in the environment. Unfortunately, the Bind utility requires a complete path for all files.

SLIDING IN SMOOTHLY

As developers contemplate how to approach OS/2 in their business endeavors, they should consider family-mode applications as a favorable way to get acquainted with the new operating system and remain commercially viable in the DOS market. Dual-mode applications are an alternative to jumping head first into OS/2-only applications or, on the other hand, burying heads in DOS-only programs.

Family-mode applications involve some limitations, however. They require larger .EXE files and more memory than pure DOS applications, they cannot perform interprogram communications or multitasking within a single program, and they provide slightly slower loading in real mode. On the positive side, execution speed is not affected at all in protected mode and very slightly in real mode.

Several advantages are apparent with family mode. First, users running family applications in OS/2 can take advantage of greater-than-640KB memory and multitasking as it applies to running several programs at a time (not running more than one thread of execution within a single program). In addition, applications that run under both operating systems make maintenance and distribution easier. Finally, family-mode applications provide a way to discover the potential of OS/2, without abandoning DOS.

David A. Schmitt is president of Lattice Inc., which is now a subsidiary of SAS Institute. Schmitt has recently directed the adaptation of the entire Lattice C library to OS/2.

LISTING 1: FAMDEMO.ASM

```
;**************************************************
;                                                *
; Demonstration family-mode program.             *
; Assemble, link and bind with OS/2 build tools. *
;                                                *
;**************************************************

        EXTRN   DOSEXIT:FAR
        EXTRN   VIOWRTTTY:FAR
        EXTRN   DOSGETMACHINEMODE:FAR

STACK   SEGMENT STACK PARA 'STACK'
        DB      2048 DUP(?)
STACK   ENDS

DGROUP  GROUP   DATA

DATA    SEGMENT WORD PUBLIC 'DATA'
MSG1    DB      "HELLO WORLD! I'M RUNNING IN "
MSG1LEN EQU     $-MSG1
MSG2    DB      'REAL MODE'
MSG2LEN EQU     $-MSG2
MSG3    DB      'PROTECTED MODE'
MSG3LEN EQU     $-MSG3
MODE    DB      ?
DATA   ENDS

CODE    SEGMENT BYTE PUBLIC 'CODE'
        ASSUME  CS:CODE, DS:DGROUP

; In all modes, DS points to data segment at entry.  This is standard
; for OS/2, is performed by Stub Loader under DOS.

START:

;     Call DosGetMachineMode(&MODE)        ; determine mode
        PUSH    DS                         ; push far address
        MOV     AX,OFFSET DGROUP:MODE
        PUSH    AX
        CALL    DOSGETMACHINEMODE

;     Call VioWrtTTY(&MSG1, MSG1LEN, 0)  ; write 1st message
        PUSH    DS
        MOV     AX,OFFSET DGROUP:MSG1
        PUSH    AX
        MOV     AX,MSG1LEN
        PUSH    AX
        XOR     AX,AX
        PUSH    AX
        CALL    VIOWRTTTY

        TEST    MODE,1                     ; which mode?
        JZ      REAL
        MOV     AX,OFFSET DGROUP:MSG3      ; protected mode msg
        MOV     BX,MSG3LEN
        JMP     SHORT WRITE2
REAL:   MOV     AX,OFFSET DGROUP:MSG2      ; real mode msg
        MOV     BX,MSG2LEN

;     Call VioWrtTTY(&MSGx, MSGxLEN, 0)
WRITE2: PUSH    DS
        PUSH    AX
        PUSH    BX
        XOR     AX,AX
        PUSH    AX
        CALL    VIOWRTTTY

;   Call DosExit(0, 0)                     ; terminate
        XOR     AX,AX
        PUSH    AX
        PUSH    AX
        CALL    DOSEXIT

CODE    ENDS
        END     START
```

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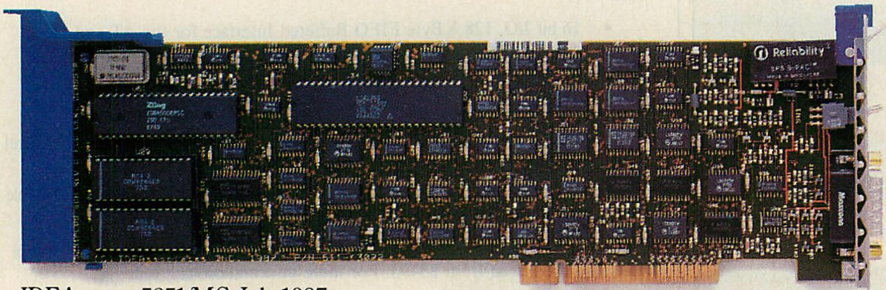

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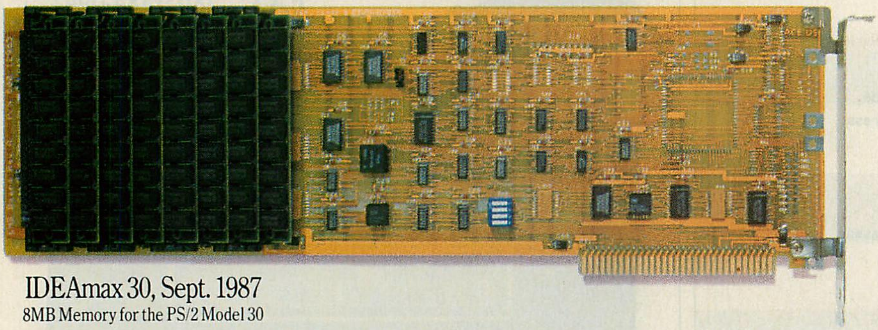

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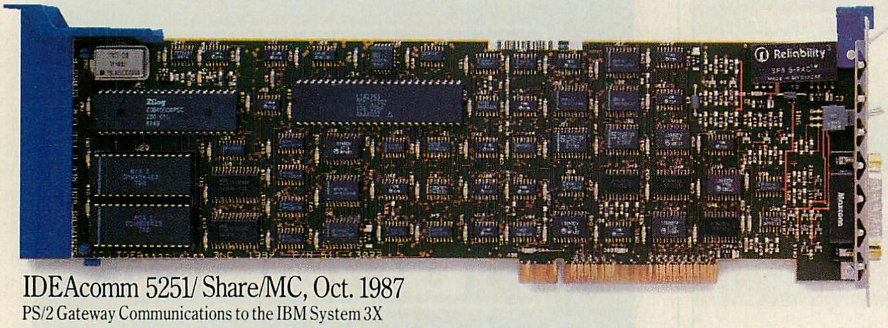

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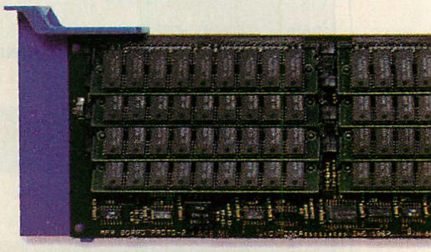

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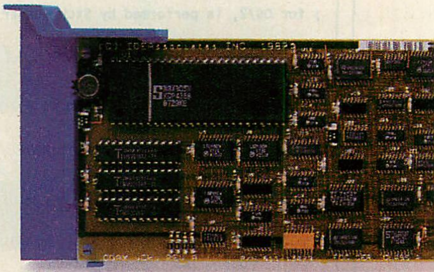

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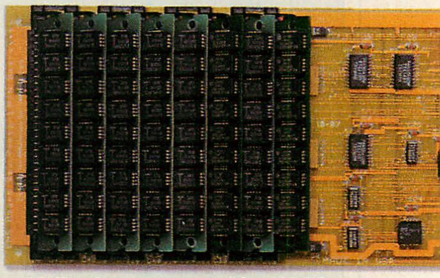

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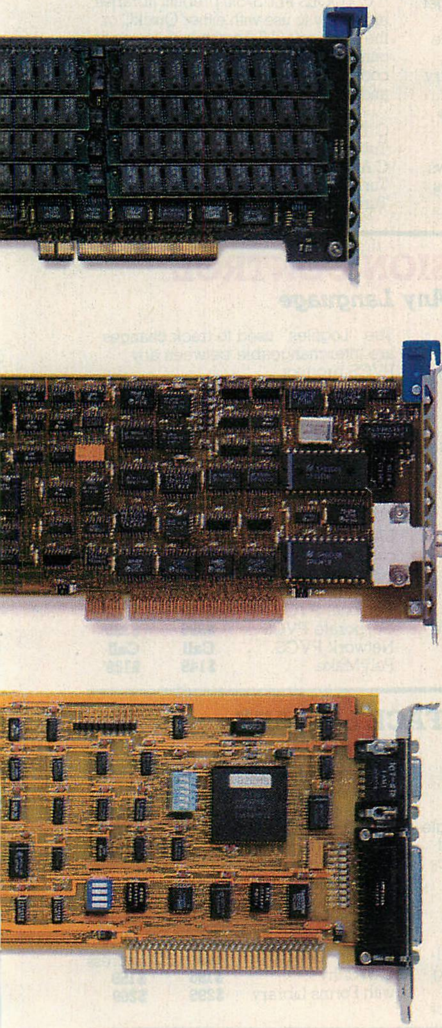

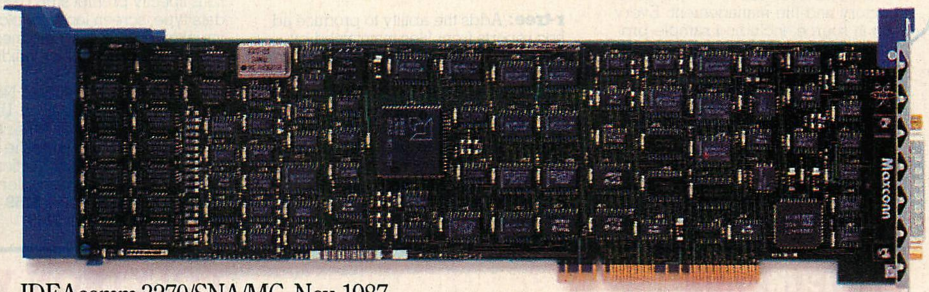

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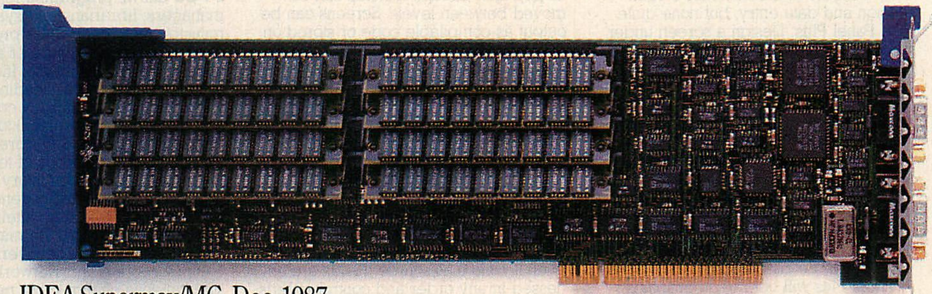

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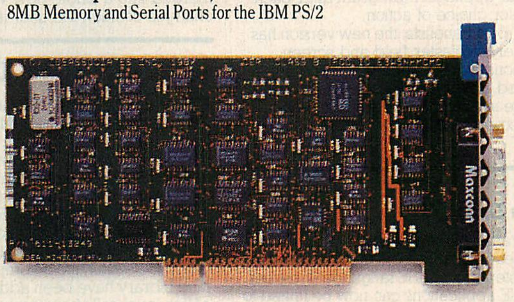

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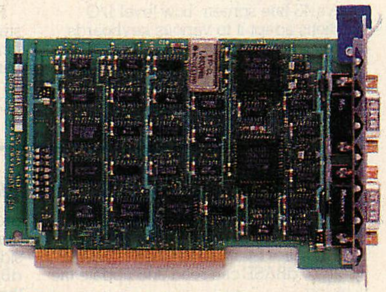

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QUICKCODE PLUS offers *dozens* of features you've *never* seen before in a dBASE code generator. Relational applications that read, display, and update a dozen or more databases simultaneously. "Real-time" calculations, performed *on screen* as the user enters each field. Forms up to 11 screens long, with the ability to pass data between screens. Computational formulas that automatically combine data from *different* databases. 9 Data types. 16 field types.

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	List:	Ours:
APPLICATIONS PLUS	**$299**	**$249**
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QUICKREPORT	**$295**	**$170**
QUICKENTRY	**$ 99**	**$ 59**

MICROSOFT LANGUAGES

Powerful Implementations Of The Most Popular Programming Languages

Microsoft C 5.0: The flagship of the Microsoft line runs up to 30 percent faster than its predecessor. Its new optimization features deliver untouchable execution speeds, 100 new additional library routines...

Microsoft MacroASSEMBLER 5.0: If you ever wanted to take on the challenge of assembly, here's your opportunity. "MASM" 5.0 is a lot easier to use, has completely revised documentation, and a new "Mixed Language" programming guide that gives you step by step instructions for linking your assembly code with other Microsoft languages.

Microsoft QuickBASIC 4.0: is a revolutionary concept in BASIC programming. It allows you to run, edit, debug, and run again. Our friends at Microsoft have eliminated the dreaded compile step. Whenever you edit your code QB4 automatically incorporates your changes, so that it can run a program of 150,000 lines in less than a minute.

Each member of this language family includes the renowned debugger CODEVIEW.

	List:	Ours:
Microsoft C	**$450**	**$295**
Microsoft Macro-ASSEMBLER	**$150**	**$109**
Microsoft QuickBASIC	**$ 99**	**$ 66**
Microsoft FORTRAN	**$450**	**$295**

NOVELL: BTRIEVE, XQL, XTRIEVE

Sophisticated Tools Essential For Fast Database Handling

Btrieve is a library of subroutines that allows the programmer to build a database application using any language. It takes complete charge of all file creation, indexing, reading, writing, insertion, deletion, forward and backward searching. Its balanced tree indexing scheme finds any key in a million in less than 4 accesses...That's fast!

Btrieve is multi-lingual also. It includes more than 20 language interfaces (including C, BASIC, PASCAL, FORTRAN). However if it turns out that you are using something a little unusual, worry not. The manual includes a chapter on how to write a language interface to Btrieve.

Btrieve's vital statistics are equally impressive. Files may have up to 24 indexes; fixed record length to 4090 characters; variable length to 64K; indexes to 255 characters; files of 4 billion bytes. Network support includes Novell, 3-COM, IBM PC NET, Software Link's Multilink and many others.

XQL is a relational database management system designed especially for programmers. Imagine being able to access your database with the ease of SQL (Structured Query Language) statements and still having the power to process that data right down to the byte level.

Think about your applications. A large part of your software development effort is probably devoted to managing data stored in files on disk. Hours spent writing lines of code to search and store data records could have been used to program more important parts of your application. Why not let XQL do it for you. XQL will increase your programming productivity and let you focus on building better applications.

The XQL system works in tandem with Btrieve and has an equally powerful chassis...No limit on the number of records per file. Max. file size is 4 gigabytes, Max. record size equals 4K, Max. indexes per file is 24. The one version works for single or multiuser systems, DOS Ver 3.0 or greater. All languages are supported.

Xtrieve is the final ingredient in the Novell programming recipe. It is a menu driven, data retrieval system, that allows you to quickly find information and display reports. System developers can easily customize Xtrieve to display command menus, help files, and error messages in the English spoken by the customer. Xtrieve screens then gives menu choices that users can quickly recognize, making Xtrieve an easy product to use and understand.

Report Option for printing customized reports, form letters, mailing labels & statements.

	List:	Ours:
Btrieve	**$245**	**$175**
Btrieve/N	**$595**	**$445**
XQL	**$795**	**$595**
Xtrieve	**$245**	**$220**
Xtrieve/N	**$595**	**$459**
Report Option	**$145**	**$128**
Report Option/N	**$345**	**$269**

GSS GRAPHICS SYSTEM

Leave the Device Driving to GSS

For serious applications stick to the tools that stick to the standards. Not the least of reasons why GSS™ has emerged as the pre-eminent graphics toolmaker is that it has always conformed to ANSI standards.

At the heart of the system is the CGI standard Development Toolkit. It has all language interfaces and device drivers for keyboards, mice, joysticks, tablets, printers, plotters, cameras. The drivers completely insulate your application from concern for device idiosyncracy.

GSS Kernel™ conforms to ANSI's GKS 2b and has all its drivers and language bindings. Macro level tools to draw, color, segment, transform, store and recreate an object. The Metafile Interpreter reads ANSI CGM files with full CGI capability for recreation on various devices.

Quality software? IBM thinks so. They sell GSS under their own label. Royalties. Needs 256k.

	List:	Ours:
CGI Dvlpment Toolkit	**$495**	**$425**
Kernel System	**$495**	**$425**
Kernel for IBM RT	**$795**	**$645**
Metafile Interpreter	**$295**	**$265**

CLIPPER $399

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FRONTRUNNER *(a new Ashton Tate product created by Apex Software)*

FrontRunner generates memory-resident **pop-up** applications using the dBASE III Plus or dBASE IV programming language. Once your memory-resident program is created, **pop-up** your program while using Lotus 1-2-3, any dBASE program, Clipper, Basic, any word processor, DOS or any program written in any language. Pop-In and Pop-Out of any software package instantly. All data files and indexes created are dBASE compatible. FrontRunner applications can be compiled into binary files for protected distribution and unparalleled speed. The user selects a hot-key to call up an application. Use the unique POWERKEY feature to define additional hot-keys within the application. A powerful paste command allows the user to extract data from a FrontRunner application into a word processor, spreadsheet or other application. Use FrontRunner for **pop-up** help screens, account listings, phone directories, schedules, random notes, printing mailing labels.... anything imaginable.

FrontRunner....List: **$295**, Ours: **$195** *(new low price!)*

GREENLEAF LIBRARIES

Functions

C source, assembler source, and binary libraries of 225 functions for many compilers. Emphasizes tight functional groupings to minimize loading code which your application may never use. Manual's 250 pages help select functions, as do demos, bulletin board.

Communications

Communicate from within your own C programs! Over 120 functions and demo programs in C and assembler source to set up interrupt-driven asynch communications for up to 16 channels. Up to 9600 baud, ASCII or binary, any parity or word length, 8250 UARTs, Xon/Xoff and Xmodem, WideTrack receive. Goodbye separate communications software. Specify compiler.

Data Windows

Windows, menus and data entry do work together...when you utilize Greenleaf's screen architect. This smooth screen designer offers device independence, logical windows, table driven data entry and economical pricing. Source code is also available.

	List	Ours
Communications	$185	$139
Functions	$185	$139
Data Windows	$295	$249
Complete 3 in 1 Pack	$665	$475

Shopping List for the Power Workbench

ASSEMBLER

	LIST	US
Microsoft Macro Assembler with Utilities	150	109
PASM 86 *by Phoenix, Macro Assembler*	195	109

ASSEMBLER Support

	LIST	US
Btrieve Softcraft's File Manager	245	175
GSS CGI....*Device independent graphics*	495	425

BASIC

	LIST	US
Microsoft BASIC Interpreter..*for XENIX*	350	249
Microsoft QuickBASIC...*Ver 4.0*	99	66
Turbo BASIC.......*NEW from Borland*	100	75

BASIC LIBRARIES & UTILITIES

	LIST	US
Btrieve Softcraft's File Manager	245	175
GSS CGI....*Device Independent Library*	495	425
Halo Graphics by Media Cybernetics	325	249

C LANGUAGE COMPILERS

	LIST	US
C86 PLUS by Computer Innovations	497	397
Lattice C Compiler Now ver 3.2	450	299
Let's C Compiler from Mark Williams Co	75	55
Mark Williams C full development system	495	369
Microsoft C Compiler with free CODEVIEW	450	295
Microsoft QuickC....*Special Price*	99	66
Turbo C.......*New from Borland*	100	75

C LIBRARIES—Communications

	LIST	US
Asynch Manager by Blaise	175	135
Greenleaf Communications	185	139
Essential Communications	185	125
Essential Communications Plus	250	189

C LIBRARIES—FILE MANAGEMENT

	LIST	US
Btrieve Softcraft's File Manager	245	175
Btrieve/N File Management for Networks	595	445
Ctree by Faircom,with full source	395	299
Rtree...*Report Gen. for Ctree*	295	235
Ctree & Rtree.....*Special Combination*	650	499
dBC ISAM Accesses dBase files	250	175
with Source code	500	349
dBC III Plus multiuser	750	595
with Source code	1500	1195
Opt Tech Sort Super fast sort for Btrieve	149	105
XQL....SQL *from NOVELL*	795	595

C LIBRARIES—Graphics

	LIST	US
Essential Graphics...*no royalties*	299	225
GSS CGI....*Device independent graphics*	495	425
GSS Metafile Interpreter stores images	295	265
Halo '88 by Media Cybernetics	325	249
Halo for Microsoft Languages	595	434

C LIBRARIES—Screen Design

	LIST	US
Curses from Lattice,UNIX lookalike	125	99
with source	250	199
C Worthy....*by Custom Design Systems*	195	159
C Worthy with Forms	295	269
Greenleaf Data Windows	295	225
Microsoft Windows Dev. Toolkit	500	365
Panel Plus by Roundhill	495	395
View Manager for C,Blaise	275	199
Vitamin C...*Creative Programming*	225	198
VC Screen...*Source code Generator*	100	81
Windows for C	195	149
Windows for Data	295	259
Zview....*Data Management Consultants*	245	175

C UTILITY LIBRARIES

	LIST	US
Basic C....*Basic-like routines for C*	175	139
Blaise C Tools Plus/5.0....*f/MsC & QuickC*	129	99
Blaise Turbo C Tools...*f/TurboC*	129	99
C Food Smorgasbord by Lattice	150	109
C Utility Library by Essential,300 functions	185	119
Greenleaf Functions	185	139
PforCe by Phoenix, vast library	395	199

OTHER TOOLS

	LIST	US
BASTOC...*JMI,Translates BASIC to C*	495	399
dBX Translator......*dBASE to C translator*	550	419
with Library Source	950	725
Pre/C....*by Phoenix, like UNIX lint*	295	154
PC-LINT..*by Gimpel, subset of UNIX Lint*	139	125

COBOL

	LIST	US
Micro Focus COBOL/2	900	795
Micro Focus Toolset	900	795
Micro Focus Personal COBOL	149	134
Microsoft COBOL inc. COBOL Tools	700	499
for XENIX	995	749
RM/COBOL...*by Ryan McFarland*	950	675
RM/COBOL 85...*ANSI 85*	1250	895

COBOL Support

	LIST	US
Btrieve Softcraft's File Manager	245	175
GSS CGI....*Device independent graphics*	495	425
Halo.......*from Media Cybernetics*	325	249
RM/Screens..*Screen generator*	395	335
RM/Net+ 5...*R/M COBOL networking*	300	249

DBASE & RELATED PRODUCTS

	LIST	US
Applications Plus....*Fox & Geller*	299	249
Brief & dBrief..*Editor/Macro lang for DBase*	275	219
Clipper.....*Nantucket's DBase Compiler*	695	399
DATA-p..........*Wallsoft*	60	50
dBC III Plus supports multiuser commands	750	595
with Source code	1500	1195
dBC ISAM...*accesses dBase files*	250	175
with Source code	500	349
dBX Translator......*dBASE to C translator*	550	419
with Library Source	950	725
dFlow.......*Wallsoft*	149	124
Documenter.......*Wallsoft*	295	244
FoxBase+.....*Fox Software*	395	219
Multiuser version	595	349
QuickCode Plus........*Fox & Geller*	295	170
QuickEntry............*Fox & Geller*	99	59
QuickReport...........*Fox & Geller*	295	170
UI Programmer....*Wallsoft*	295	244

FORTRAN Compilers & Utilities

	LIST	US
Btrieve: Softcraft's File Manager	245	175
GSS Graphics Development Toolkit....*CGI*	495	425
GSS GKS...*Kernel Sys,ANSI Level 2b*	495	425
Halo '88.......*from Media Cybernetics*	325	249
Microsoft Fortran..*Ver 4.0,inc. Codeview*	450	295
for XENIX	695	499
R/M Fortran...*ANSI 77 by Ryan McFarland*	595	425
for XENIX	750	599
Spindrift Library....*By Spindrift Labs*	149	129

PROLOG

	LIST	US
APT..*PROLOG Tutor*	65	59
Arity PROLOG Compiler & Interpreter	650	569
Arity PROLOG Interpreter	295	229
Arity Standard PROLOG	95	77
PROLOG-86 Plus.........*Solution Systems*	250	199
Turbo PROLOG...*Borland Intl.*	100	75
Turbo PROLOG Toolbox...*Borland*	100	75

TEXT EDITORS

	LIST	US
Brief......*from Solution Systems*	195	155
dBrief..*Macro lang for Brief & DBase*	95	75
Brief & dBrief Combo	275	219
Condor Editor....*Condor Corp SUPER SALE*	130	65
Epsilon.....*Lugaru*	195	149
KEDIT.....*Mansfield..identical to XEDIT*	125	99
KEDIT Ver. 4.0	150	119
Pmate.....*Phoenix*	195	109
Vedit Plus.........*Compuview*	185	129

DEBUGGERS

	LIST	US
Advanced Trace 86.....*Morgan*	175	119
C-Sprite...*Source debugger for Lattice C*	175	139
Periscope I...*Board, Switch, Software*	345	289
Periscope II..*Breakout Switch & Software*	175	139
Periscope II.....*Software only*	145	105
Periscope III....*8 Mhz*	1095	875
Periscope III...*10 Mhz*	1195	975
Pfix 86 Plus....*Phoenix symbolic debugger*	395	199

LOGITECH

	LIST	US
MODULA-2 Compiler Package	99	79
MODULA-2 Development Pkg	249	199
MODULA-2 Toolkit	169	139
MODULA-2 ROM Package	299	239
MODULA-2 Window Package	49	39

PHOENIX

	LIST	US
Pasm 86......*Macro ASSEMBLER*	195	109
Pdisk......*Disk Management Utility*	145	95
PFantasy.....*six-pack take-away*	995	569
PFinish......*Profiler*	395	199
PFix 86 Plus.Symbolic Debugger	395	199
PForCe.......*Utility library*	395	199
PforCe...*Pforce for C*	395	199
PLink 86+ ...*sophisticated overlay linker*	495	269
PMaker.......*make utility*	125	74
Pmate........*Text Editor*	195	109
Pre-C........*Super-set of UNIX Lint*	295	154
Ptel.........*Binary Transfer Program*	49	39

POLYTRON

	LIST	US
PolyBoost....*Software accelerator*	80	64
PolyDesk III..*3rd Generation Desktop org*	99	73
PolyLibrarian...*Library Manager*	99	89
PolyLibrarian II	149	129
PolyMake......*Complete MAKE Utility*	149	129
PolyShell.....*UNIX-like Command Shell*	149	109
PolyXREF2...*Cross Reference Util all lang*	219	169
PolyXREF2...*Single Language support*	129	99
PVCS Corporate...*Source Code Control*	395	329
PVCS Personal...*Personalised ver of above*	149	129
PVCS Network...*Powerful Ver. of PVCS*	Call	Call

RYAN McFARLAND

	LIST	US
RM/COBOL......*ANSI 74 Standard*	950	675
for UNIX or XENIX	1250	999
RM/COBOL 85.....*ANSI 85 Standard*	1250	895
RM/FORTRAN.....*ANSI 77 Standard*	595	425
for UNIX or XENIX	750	599
RM/NET+5...*COBOL Networking*	300	249
RM/Screens.....*COBOL 85 Screen generator*	395	335

SOFTCRAFT

	LIST	US
Btrieve Softcraft's File Manager	245	175
Xtrieve...*Query language for Btrieve*	245	220
Report Option for Xtrieve	145	128
Btrieve/N File Management for Networks	595	445
Xtrieve/N.....*Multi-User Query*	595	459
Report Option/N...*Multi-user Rep Opt*	345	269
XQL......*SQL for Btrieve*	795	595

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CIRCLE NO. 233 ON READER SERVICE CARD

PRODUCT WATCH

Reviews and Updates

TRIAD PLUS
Micronyx Inc.

WATCOM C 6.0
WATCOM Products Inc.

TRIAD PLUS
Micronyx Inc.
1901 North Central Expressway
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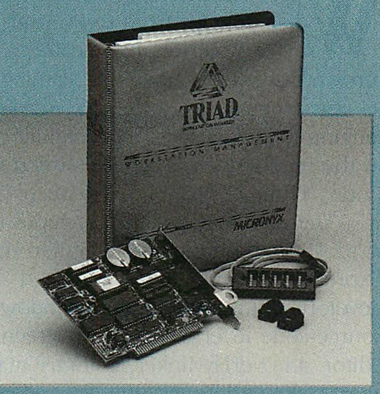
Richardson, TX 75080
214/690-0595

PRICE: $695



CIRCLE 349 ON READER SERVICE CARD

As corporations increasingly recognize information as a valuable resource, security becomes a greater concern. Putting locks on file cabinets can solve one problem, but even more extensive security measures are needed for PCs with hard disks. One possible solution is Triad Plus from Micronyx Inc., a half-size add-in board with support software that secures individual workstations and their valuable data.

Triad Plus controls access, encrypts data, and monitors PC usage. Its control mechanism not only can restrict which users can access a PC, but it also can restrict a PC's access to a network. Triad Plus's data encryption can be extended beyond local drives to files that a protected workstation stores on an otherwise unprotected network. Built-in auditing and accounting features not only can track how and when a PC has been used, but which components have been accessed.

The board restricts user access by intercepting all DOS, BIOS, and direct hardware I/O calls. It contains a data-ciphering processor with a proprietary cryptographic algorithm, a system-wide "master phrase" and other system-generated keys. As files are written to disk, the processor encrypts the data; as files are read from a disk, it decrypts the data. The encryption process remains totally transparent to the application. Although the files still may be viewed, their encrypted contents are meaningless. The user or workstation administrator can encrypt all files or a select few at a PC for individual, group, or specific-machine access.

Because the Triad Plus board has its own processor, it functions more efficiently than software-only products. Although the overhead is noticeable, it is less discernible than software encryption methods. Triad Plus encrypts or decrypts a 50KB file in less than one second. Certain functions, including directory searches and others requiring intense I/O, are noticeably slower on a PC/XT. Degradation on a PC/AT, on the other hand, is not as noticeable.

The board requires a unique interrupt-request line; 2, 5, or 7 can be selected. Although the board address can be jumpered for either D000H or E000H, only D000H can be used on an AT. This makes Triad Plus incompatible with many expanded memory boards that use D000H for paging. Micronyx provides a pair of utilities to monitor, interrupt, and address space use. The monitoring utility, SYSWATCH, is run before installation. After exercising the machine, the installer executes the reporting utility, SYSCHECK, which recommends address and interrupt jumper setups. Other than that, installation is a straightforward exercise of inserting the board. Because an administrator's functions are necessarily more complex than a typical user's functions, separate manuals are provided.

If the Triad Plus board is removed from the system unit, all encrypted files are accessible, although their contents remain encrypted. Removing the board also intentionally destroys all user security information that is stored in the board's memory. The security administrator must then reinitialize the board before it can be used.

When a Triad Plus-equipped PC is booted, the board interrupts the booting process and takes control. To continue the boot process, the board requires the user to type a primary ID and a secondary ID, to insert a token (a tiny black plastic box with information unique to the user) into a connector cabled to the board, and, finally, to enter in the matching password. The Triad Plus board keeps track of any incorrect password attempts and can lock out access to a user for a prescribed "lock-out period" after a set number of invalid attempts.

The system administrator programs access information into the token using the Triad Plus board and the configuration software supplied with the system. A token has 256 bits of access data including an encoded password.

Two on-board batteries—a primary and a backup—maintain the entire contents of on-board memory, where the Triad Plus administrative utility, MANAGER, stores the PC's access patterns. If the PCs in a work group have similar access patterns, the configuration can be stored and used on any of the machines in the work group.

A manager can define IDs and access profiles for a maximum of 64 users on each PC that Triad Plus protects. Access to a PC can be controlled for up to four daily time periods that can vary based on the day of the week. As an option, users can be required to enter department numbers and project account numbers during the LOGON operation. If a user wishes to walk away from a protected PC that is in the

middle of a task, a SUSPEND command can be issued at the DOS prompt, or an equivalent user-defined, hot-key sequence can be used. However, after the SUSPEND command has been invoked, the PC must be revalidated before any work can continue.

Triad Plus intercepts diskette and hard disk I/O at the BIOS level for compatibility reasons. Other communications devices (parallel, async, IRMA 3270, and LAN cards) are secured at the port level. To access any of the supported hardware resources, a user must have an appropriate device access permission. Using the system administration utility, eight groupings of permissions can be defined. These permissions can be applied either with or without an implied hierarchy. If the hierarchy option is enabled, the subwindow will display all possible permissions from a low state to a high state. This process eases entry of access state data. Access states can be named, usually according to the rank of the user. The lowest access state is often assigned to "guest" users, who can be allowed access without a token.

Once users boot up their systems, Triad Plus audits LOGONs, LOGOFFs, LOGON failures, project registrations, DOS program command-line invocations, session suspends, failures to end suspension, I/O access violations, and file access violations. The Triad Plus board securely stores the audit data, writing it to a file when the buffer is full. A supplied utility produces a straightforward report of the audited data. The data format of the audit record is provided in the documentation for administrators who wish to write customized reports.

Users and administrators have a number of commands to protect data. The OWNER command establishes ownership attributes for new files created in a session. A file may be defined as to "who" may access it (person or group) and "where" it may be accessed (single machine or group of machines). An attribute specification of "public" turns off encryption, causing files to be stored in "plain text."

To prevent a workstation owner from holding files hostage, the Triad Plus administrator has unrestricted access to files. The administrator uses the commands ORPHAN and OVERRIDE to view protected file attributes and decrypt, delete, copy, or rename files.

The PROTECT command causes an existing file or set of files to be encrypted; the UNPROTECT command causes the file to be decrypted. Wild cards can be used to specify groups of files. Sometimes it is important to keep a file encrypted—for example, when sending a file over a communications link. Because encrypted files are automatically decrypted while they are read from disk, a special process is necessary to preserve the encryption; this process is controlled by the EXPORT and IMPORT commands.

For added security, Triad Plus has a configuration option that forces protected files to be overwritten with random data when they are deleted from the disk. Another Triad Plus configuration option hides protected files when unauthorized users make a request for a directory display.

Because Triad Plus has the ability to control access to network adapters, users can be blocked from all access to the network, based on the ID and password supplied to that workstation. This allows a workstation to be set up so that only certain users can use it in conjunction with the network, even if those users can access the network from other workstations.

In a network environment, Triad Plus runs only on the workstations and not on the file servers, providing access control and allowing encryption and decryption of files stored on the file servers. Anyone with network access to a file, such as the network manager, can delete the file or can copy it in encrypted form.

If a large number of workstations are on a network, putting a security board in each one is an expensive substitute for a good network security system. In addition, the coordination of security information is time consuming. However, Triad Plus is a practical choice to protect a few network workstations, particularly those workstations whose owners have sensitive information that must be protected from the network administrator.

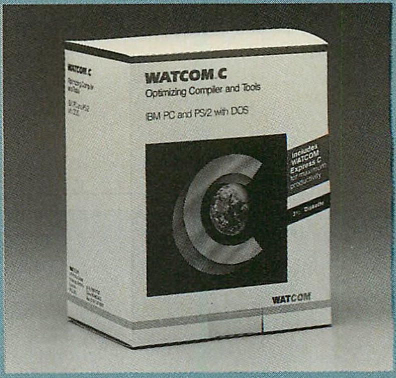
On or off a network, data must have more than a casual significance to justify Triad Plus's $695 price and the expense of its performance overhead and installation. However, its price also includes a higher level of protection. The U.S. Department of Defense National Security Center gave the product a rating of PC-2, the highest rating ever given to a PC security system and a higher rating than any software-based system. When security is of paramount importance, Triad Plus can be trusted to protect any valuable data.

—ART KRUMREY

WATCOM C 6.0

WATCOM Products Inc.
415 Phillip Street
Waterloo, Ontario, CD N2L 3X2
519/886-3700

PRICE: $295



CIRCLE 352 ON READER SERVICE CARD

WATCOM, a privately held Canadian spin-off from the University of Waterloo, has clearly thrown down the gauntlet by naming its new language package C 6.0, challenging Microsoft C 5.0's preeminence in the market (see "Highly Polished C Code," Philip N. Hisley, this issue, p. 76).

The complete package includes the WATCOM C 6.0 optimizing compiler, the Express C compiler with integrated development environment, a windowed source-code level debugger, a screen editor, an overlay linker, a library manager, Make and Touch utilities, and an object disassembler.

WATCOM has been actively developing and marketing computer languages and development support utilities since 1974. Available products include document processing, data management, and network-support software. WATCOM language packages include APL, BASIC, COBOL, Pascal, Prolog, FORTRAN-77, Modula-2, and C.

A full-bore optimizing C compiler compatible with ANSI's August 3, 1987, draft standard, WATCOM's C 6.0 performs excellent code optimization. The compiler effectively uses the limited 80*x*86 register set and addresses the problem of function call overhead by passing as many function parameters as possible in registers. This approach minimizes the overhead incurred by pushing parameters onto the stack prior to a function call and restoring the stack upon function return.

The compiler provides a set of *pragmas* (compiler directives) that not only support normal compiler options, such as stack limit checking and gener-

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ation of in-line machine code, but also permit exact specification of function calling and return sequences. This permits matching the parameter passing protocol of most function libraries.

The user can control compilation through command-line options, such as specifying the memory model (small, medium, compact, large, or huge), the processor instruction set, and the generation of 80*x*87 math coprocessor instructions. The optimization level to be performed also can be indicated: none (for debugging purposes), optimize for space or time, use intrinsic functions, and optimize loops. Although loop optimization can be selected, the *PC Tech Journal* optimization benchmark did not indicate that C 6.0 performed this optimization. To maintain compatibility with other C compilers, C 6.0 supports the nonstandard variable type specifiers: **cdecl**, **far**, **fortran**, **huge**, **near**, and **pascal**. It also has an ANSI-compatible standard function library.

ALL-IN-ONE

Express C can be invoked as a stand-alone prototyping compiler or as part of the integrated development environment. (If desired, Express C can be purchased separately for $75.) Both a source-level debugger that permits code animation and a screen editor that can edit multiple files are included. When using the integrated environment, the screen editor serves as a text modification tool and as the command interface for invoking the compiler and debugger.

Whether the compiler is invoked as a stand-alone program or from within the integrated environment, command-line options can be specified to control aspects of the compilation process such as directory search paths and sizing a program's stack.

If the Express C compiler is invoked from within the editor, the current editor buffer is compiled; if error free, the program is executed. Any errors detected during compilation are displayed and then saved in an error file. When control is returned to the editor, the cursor is placed at the first error detected. If multiple errors occur, the error file can be read into an edit window for review.

If the source-level debugger used with Express C is invoked from within the editor, the current editor buffer is compiled, and control is then transferred to the debugger. The user can control the debugging process by setting multiple breakpoints, single-stepping program execution, and stepping into and out of functions. Global and local program variables can be examined, formatted, and changed at any time during debugging. Output from a program under test can be viewed either from within a window on the debug screen or as a separate screen.

Express C supports only the medium memory model and cannot directly produce stand-alone executable programs. To generate .EXE files, the compiler must generate object files; WLINK, the stand-alone object module linker, produces .EXE files.

WLINK supports both the Express C and C 6.0 optimizing compilers. In addition to supporting the requisite functions, such as external address resolution and the searching of object module libraries, the linker allows specification of arbitrarily complex nested overlay schemes. Commands specify not only the type of debugging information (line numbering, variable typing, global symbol, and local symbol) to be included in the executable module, but also the object modules to which the specification applies. Linker commands can be passed on the command line that invokes the linker or, if there are many, submitted to the linker in a directive file.

TRACKING DOWN BUGS

C programmers are accustomed to using powerful screen-oriented source-code-level debugging tools to assist in finding bugs. WATCOM does not disappoint in this area. The debugger, named WATCOM Visual Interactive Debugging Execution Overseer (WVIDEO), is highly configurable, permitting the programmer to define the type and size of each of seven possible windows that appear on the debugging display:

- source window—displays the source code of the program under test
- assembly window—displays disassembled instructions of program tested
- dialogue window—displays responses to the debugger commands issued by the programmer
- memory window—displays contents of consecutive memory locations
- prompt window—used by the programmer for command input
- register window—displays the contents of 80*x*86 registers associated with the program under test
- stack window—displays the top of the execution stack

The WVIDEO debugger provides powerful commands to trap through the code under test and examine or

"How to protect your software by letting people copy it."

By Dick Erett, President of Software Security

Inventor and entrepreneur, Dick Erett, explains his company's view on the protection of intellectual property.

"A crucial point that even sophisticated software development companies and the trade press seem to be missing or ignoring is this:

Software protection must be understood to be a distinctively different concept from that commonly referred to as copy protection.

Fundamentally, software protection involves devising a method that prevents unauthorized use of a program, without restricting a legitimate user from making any number of additional copies or preventing program operation via hard disk or LANs.

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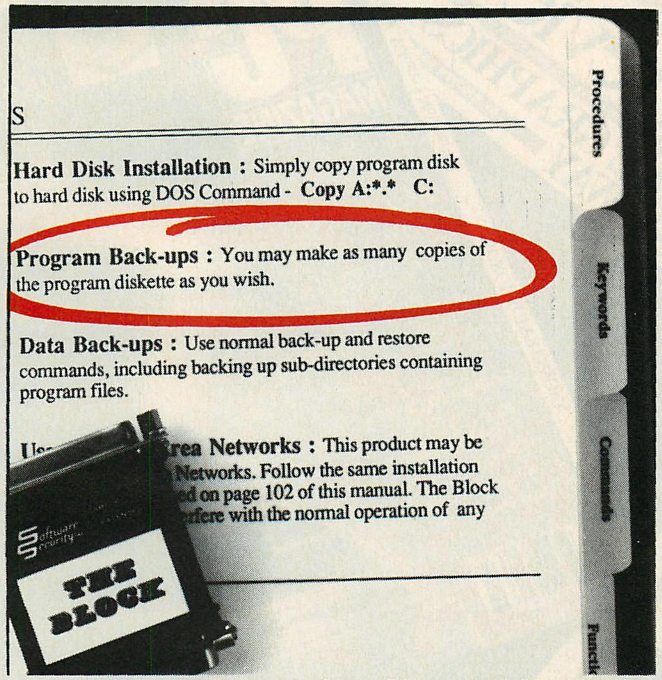

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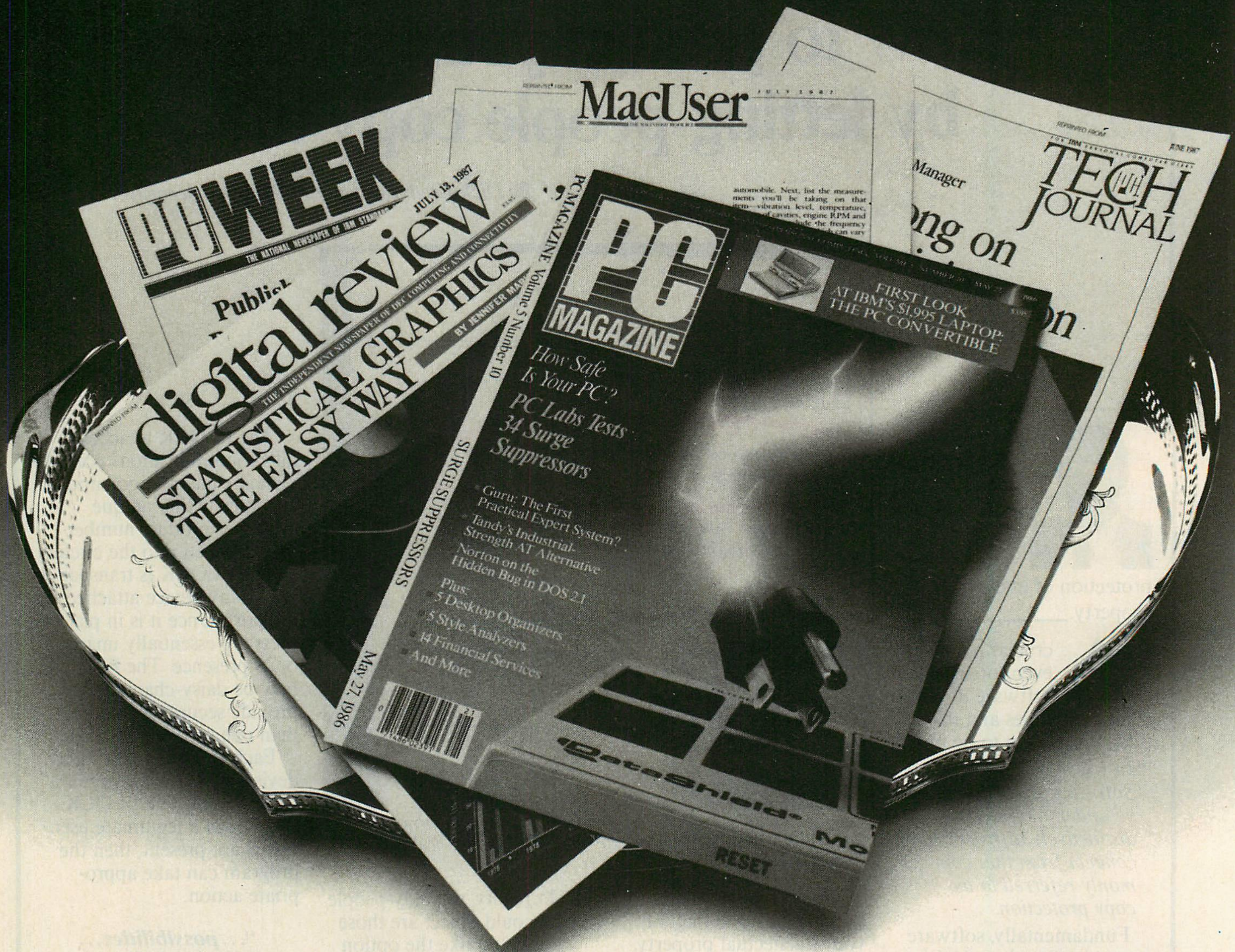

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modify registers, memory locations, or program variables. This gives programmers complete control over the debugging process; they can enter debugging commands directly in the Prompt window or by means of optional drop-down menu windows invoked by Alt-key combinations.

The Break and Watch commands allow the debugger to regain control from a running program based on conditions established by the programmer. For the Break command, the conditions are explicit breakpoints; for the Watch command, they are changes in the contents of specified memory locations. The ability to attach debugging commands to breakpoints and watchpoints (which can invoke files of other debugger commands), along with the ability to use program variables and registers in the If debugger command (which is a conditional execution command), allows the programmer to create intricate debug scenarios for tracking down subtle and elusive program bugs.

Execution of a program under test is controlled by the Trace command, which animates the debugging process by one statement or function at a time. This can be done at the assembly level, the source-code level, or a combination of both. In the latter case, if the source code is available, it is stepped through; otherwise, the assembly code is stepped through. Functions associated with the Trace command—single-step, step over, step into, and return from functions—are assigned to single keys for convenience.

Examine and Modify commands display or change memory contents at the byte, word, and pointer-of-port level. For incremental debugging, a Call command can be made to any function in the system: near, far, or interrupt. A parameter list can be passed to the function. Returned values can be formatted and printed or assigned to registers, program variables, or user-defined variables.

A POLISHED PACKAGE

The WATCOM C 6.0 package comes with a set of complete, well-written, indexed, and functional documentation. A fold-over leaf on each guide acts as a bookmark, and titles are clearly visible on the bindings.

The Optimizing Compiler and Tools User's Guide provides instructions on using the optimizing C compiler, the linker, the WVIDEO debugger, and the other support utilities. It also describes the 80x86 architecture, calling conventions used by the compiler, use of pragmas to customize compilation, and installation. The *Express C User's Guide*, because it can stand alone, duplicates some of the content of the optimizing compiler guide. In addition, it contains a description of the integrated development environment.

The *Language Reference and Programmer's Guide* presents the formal definition of the C language and WATCOM C 6.0 implementation-dependent aspects. The *Library Reference* describes each library function provided with the WATCOM C 6.0 package in the UNIX format. To aid the developer in writing portable code, each function is classified as ANSI-compatible, POSIX-compatible, DOS-specific, or WATCOM-specific. The *WATCOM Editor User's Guide* documents the capable, but uninspiring screen editor.

From its powerful optimizing compiler to its excellent documentation, WATCOM's C 6.0 package may prove that even in the crowded and competitive C market, there is room for a product that can stand on its merit and technical prowess. This new entry deserves serious consideration.

—PHILIP N. HISLEY

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1 QB4 BUG
2 TYPE DEFS
3 STRING ENVIRON

Microsoft's QuickBASIC 4.0 (QB4), with its two language processors and integrated development environment, is a complicated piece of software that cannot be explored fully in a single review, no matter how thorough. One month after running the review (see Product Watch, May 1987, p. 149), we have information on a bug and some strange behavior in the editor.

The first item is a bug report from Selden P. McCabe, principal of Programming Entrepreneurs, a PC consulting and custom-programming firm in Redmond, Washington. Happily, Microsoft already has a new release of QuickBASIC that solves this and other problems. However, if you cannot wait to receive it, Mr. McCabe offers a simple work-around.

In the course of working with Mr. McCabe's submission, I discovered that the QB4 editor does some strange and unexpected things to source files, and then lies about it. The problem is especially significant if you edit source code both within the QB4 environment and with another editor outside of it.

A third item, not related to QB4, is the result of observations made by executive editor David Methvin after he had some problems getting programs to recognize variables in the DOS environment. Keeping in mind a simple but often overlooked fact about how DOS stores environment strings could help you in diagnosing some pesky software problems.

1 QUICKBASIC PARAMETER BUG

QB4 consists of two language processors. The first, QB.EXE, maintains the interactive development environment; it is an incremental compiler that converts source code to threaded p-code and then executes it interpretively. The other, BC.EXE, is a command-line compiler that produces native-code executable files. The advantage here is that each compiler can be tailored to a different purpose. The p-code interpreter trades execution speed for compilation speed, resulting in lightning-quick turnaround during development. Once testing is completed, the BC compiler generates production code that is not hindered by an interpreter.

The disadvantage of this approach is that each compiler produces different code. As a result, the program developed with QB.EXE during the testing cycle is not the same as the one produced by BC.EXE. A program that works fine in the interactive environment can suddenly break when compiled to an .EXE file. As an example, consider this program that uses a passed parameter as a loop index:

```
I% = 199
CALL DOTEST(I% )
PRINT "After return, I is "; I%
SUB PARMTEST( J AS INTEGER)
FOR J = 1 TO 3
  PRINT "In Loop "; J
NEXT J
PRINT "After loop, J is "; J
END SUB
```

When run in the interactive environment, the same program produces correct output as follows:

```
In Loop 1
In Loop 2
In Loop 3
After Loop, J is 4
After return, I is 4
```

However, when this program is compiled to an .EXE file, it reports a value of 0 after the loop and of 199 after return (within the loop, the three values are printed correctly). The error occurs whether the .EXE file was created by running BC from within the environment or from DOS, and whether it is a stand-alone program or uses BRUN40.EXE.

The reason for the bug can be readily discovered by examining the program with the CodeView debugger (not supplied with QB4, but available with other Microsoft language processors). Within the loop, the loop index is established in a temporary variable. At each iteration, the program prints the correct value of the index from the temporary and also attempts to copy it into the location of the parameter. The sequence of instructions that do this, however, is wrong.

In QuickBASIC, parameters are passed to BASIC subroutines by reference, meaning that the caller pushes onto the stack the address of each parameter. In the example program, the instruction sequence for storing the index into the parameter is generated as if the parameter had been passed by value. That is, the index is stored into the stack instead of into the location whose address is on the stack. This occurs only within the loop; thereafter, the parameter is accessed through its address on the stack, or at least through what *was* the address.

But the stack location has been overwritten by the spurious store; in the example, the address location contains the value 4. Therefore, the print statement after the loop prints the value at offset 4 of the data segment. If the subroutine were to change the parameter's value after the loop, it would write into an unpredictable location, corrupting the data segment and possibly causing an eventual system crash. Upon return to the caller, the argument value is unchanged because the subroutine never wrote into the address where the caller stored the argument.

This bug, along with a few others, has been fixed in a maintenance release of QuickBASIC, version 4.00b. Owners of the initial release of QB4 can obtain the new version at no cost; for information, call Microsoft Corporation at 206/882-8080.

In the meantime, however, Mr. McCabe suggests a simple work-around of using a local variable, not the parameter, as the loop index:

```
SUB PARMTEST(J AS INTEGER)
FOR INDEX% = 1 TO 3
  J = INDEX%
  PRINT "In Loop "; J
NEXT INDEX%
J = INDEX%
PRINT "After loop, J is "; J
END SUB
```

Although in this simple example it is not necessary to assign the index to *J* every time through the loop, it would be required in a more complex program that incorporates conditional exits from the loop.

2 QUICKBASIC TYPE DECLARATIONS

Back in the days when BASIC programs had to be line-numbered, one of the considerations facing a programmer was how line numbers were treated by various editors. BASIC-oriented editors that sorted lines by number and prevented duplicates were typically not very good as text processors, while powerful external editors provided no help in line numbering. Although modern BASIC dialects dispense with line numbers, the editors built into development systems still apply language-specific processing that is not easily duplicated in an external editor. One example is the handling of variable type declarations (such as DEFINT and DEFDBL) in QB4.

When a source file contains several subprograms, the QB4 editor divides it into modules, each consisting of a single subprogram. This division is for purposes of display only; the original file is kept intact, and saving any one of the modules saves them all. During editing, however, each module is considered distinct, and declarations made in one do not apply to any other. As an example, consider a source-code file with the following structure:

```
DECLARE SUBPROG(I AS INTEGER)
:
:
END
SUB SUBPROG(I AS INTEGER)
:
:
END SUB
```

Suppose that, while editing the main program with the QB4 editor, you add the statement DEFINT I-N. This declaration applies only to the main program, not the subprogram. To make sure that this is the case, when the file is processed by compilers that do not subdivide it (such as QB3 or the BC command-line compiler), QB4 automatically inserts the declaration DEFSNG I-N between the END and SUB statements. This "undoes" the main program's declaration and ensures that all subsequent variables are of the default type, single-precision real. This declaration is not visible in the QB4 editor; it can be seen only if the file is saved in text mode and examined with an external editor. The QB4 editor hides a line of code that is present in the source file.

The situation is different if a DEFINT statement is added to the main program with an external editor. When the file is read into QB4, the editor assumes that the declaration applies to the entire file. When displaying the subprogram, the editor shows a copy of the main program's DEFINT statement ahead of the SUB statement. This declaration, however, is not saved into the source file; the editor is displaying something that is not really there. If you delete this phantom declaration, the editor places a hidden DEFSNG statement, as described above, in the source file. The deletion actually *adds* something to the file.

The situation becomes even more confusing when using the QB4 editor to change, rather than add or delete, a declaration. The change is applied only to the module in which it is made, and declarations in other modules farther down the source file are added or changed as necessary to maintain the original typing. For example, say the source file contained only the declaration DEFINT I-N in the main program. The QB4 editor shows the same (nonexistent) declaration when displaying the subprogram. If the declaration within the main program is changed to DEFINT A-Z, the editor inserts DEFSNG A-H, O-Z into the source file just ahead of the SUB statement. What the editor displays, however, when the subprogram is on-screen is DEFINT I-N, the logical result of the declarations in both modules.

You must take care when editing QB4 files with both the internal editor and your favorite external text-cruncher. In any language, moving code around in a source file can drastically alter the behavior of a program. However, the QB4 editor is especially tricky because it maintains the fiction

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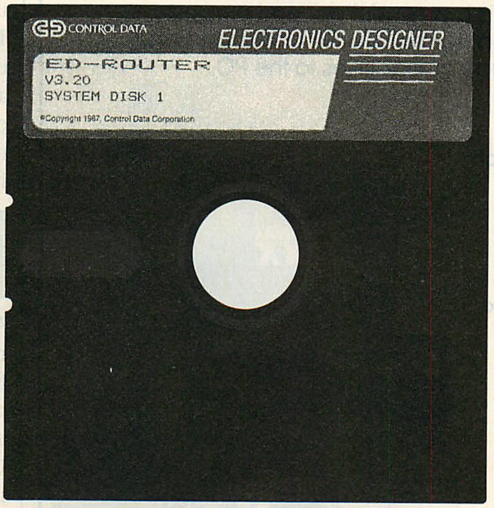

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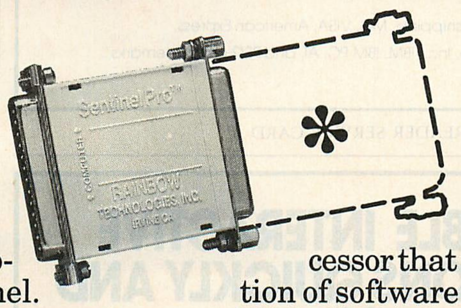

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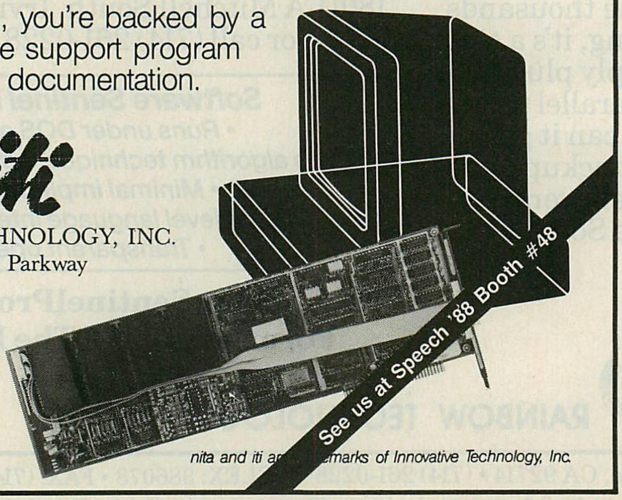

that subprograms are independent units. In fact, it treats the source file as one entity and applies type declarations incrementally rather than absolutely. Therefore, finding and correcting any unintended side effects introduced by an external editor is made more difficult by the fact that the QB4 editor is not completely open in displaying what it does to the source.

3 SPACES IN THE ENVIRONMENT

Applications are using the DOS environment more and more to store configuration information in a way that is readily accessible even to the inexperienced user. There is no need to edit CONFIG.SYS or AUTOEXEC.BAT files; merely type in a SET statement. One characteristic of the SET command, however, can cause unforeseen problems: all spaces in a SET string are significant and are stored in the environment exactly as entered. This means that environment variables containing trailing or embedded spaces are distinct from variables composed of the same characters without spaces.

The most common occurrence of spaces in environment variables is around the equal sign. Much documentation is imprecise on this point, showing the format of environment strings in proportional type that makes it difficult to determine if there are or are not spaces in the string. For example, the DOS manual, in describing the SET command, is not clear whether the COMSPEC variable should or should not be followed by a space. When in doubt, many new users type SET commands with spaces around punctuation. Thus, programs that look for particular environment variables (DOS being the prime example) cannot find them.

Although it is feasible for a program to ignore trailing spaces in the names of environment variables, I have found none that do so. Spaces to the right of the equal sign are handled differently by different programs. For example, MASM 5.0 cannot find include files if the INCLUDE environment string (a list of paths delimited with semicolons) contains blanks, but Microsoft C 5.0 ignores spaces between path names in this string.

Program failures caused by improper environment contents can be subtle and hard to diagnose. The next time you are called in to cure a user's software problem, carefully check the environment for any spaces.

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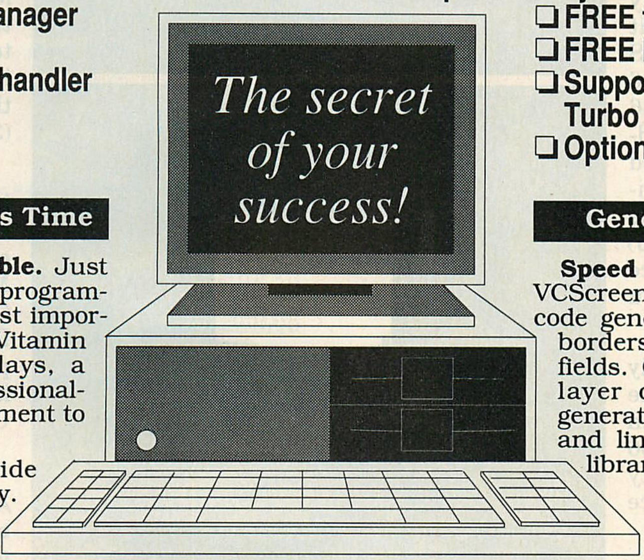

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Folklore, Fear—and Folly

P.C. Coffee

The current debate over "look and feel" obscures more fundamental problems about user satisfaction.

The lead time for this column makes it hard to strike a balance between being timely when I write it, but staying relevant until you read it. As I write this, for example, the Apple lawsuit against Hewlett-Packard and Microsoft is the hottest topic of discussion in the computer industry. By the time this article is published, however, the lawsuit may even be settled. I will lose my pundit's permit if I don't say *something* about it, but I will defer my comments until the end of the column—both my opinion of Apple and my unorthodox predictions of who stands to win from this mess.

The lawsuit reinforces my view of a problem that has been around for some time. The problem is that of overemphasizing the computational aspect of personal computing—the apparently widespread doctrine that the interface between the user and the processor/file system is the critical path toward greater ease of use. My experience in user support suggests that this is a serious case of working hardest on the problems whose solution brings creative satisfaction, rather than finding out what really gets in the users' way and fixing it—however technically trivial that may be.

THE CABLE GOD IS ANGRY

Let me tell you a story. It takes place in the office of one of my consulting clients—a small firm with two XT-class PCs, one of them an older IBM XT and the other a brand-new compatible. The story begins when they called with a problem. "The printer cable you ordered for our new system is here, but it isn't working," they said.

Terrific. I hate cable problems. One of these days I will have to get a breakout box, but it drives me crazy that even the good mail-order catalogs have printer cable selection tables that look like zip-code directories for the northern hemisphere.

When I arrived, however, the printer and cable were working fine, but the application running on the new system had a fixed left margin of zero for printed output. The printer's (non-adjustable) sheet feeder was aligning the paper an inch too far to the right. The users "saw" the printer cutting off the beginning of each line, which never happened when this printer was on the older system whose applications were set for proper margins. They concluded the cable was at fault.

Who can blame them? They constructed a reasonable explanation, given limited information, in the same way that the ancient Greeks came up with the concept of a thunder god to explain loud noises during storms.

My first question was, "Does this program really have no way to change the margins on the printout?" This led to an interesting expedition through a complete but confusing system of menus and manuals. Everything was there, but the information was arranged according to what the program did rather than what the user would be trying to do. Options and commands for output were scattered in at least five different places. The logic was clear, but at right angles to what was needed to solve end-user problems.

Perhaps the software designer should be kept away from the documentation until its essential structure is in place. Otherwise, the structure of the *program* almost inevitably overshadows the structure of the *task* that the program performs. Documentation should support the use of the product, not prove the designer's competence by serving as an inventory of requirements met and features provided.

What the developer expects a feature to be used for may have only a distant relationship to what it can actually do. I once forced a program to do quarter-page output, for example, by sticking the printer control code for page length into the optional output header. Having gotten away with this kind of jury-rig before, I naturally looked for a similar way to solve my clients' printer margin problem.

ESCAPE FROM REALITY

So far, my clients had followed my explanation well enough; the notion that the computer could reset the printer's margins was no more magical than other tasks that the machine did all the time. When I opened the printer manual and started digging up the actual control codes, however, my clients looked at me as if I were speaking

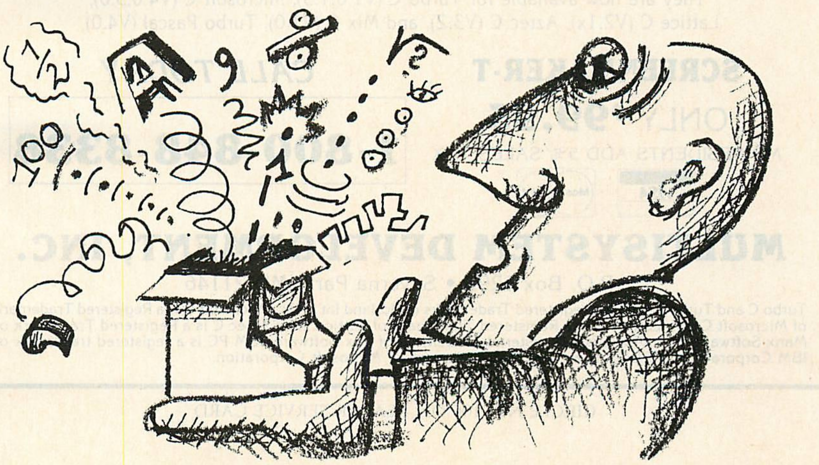

ILLUSTRATION • MACIEK ALBRECHT

Martian. "The printer left margin is reset by placing the carriage at the desired position and sending the sequence <ESC> <CR> L."

First, try to explain that "ESC" is one "letter," not the three letters *E*, *S*, and *C*. Then, try to explain that when you send the printer a group of letters beginning with this magic pseudo-character, it will not necessarily print them out. For extra credit, explain why sending the printer a carriage return does not return the carriage. Finally, explain why it is so hard to create such a sequence from the keyboard; DOS will not let you do it and neither will many text editors.

Brilliant idea: use BASIC. Almost every computer, especially the DOS-based PC, has a version of BASIC on board that can print characters to a file.

So, you can use BASIC to build a file containing the control codes for "left margin reset." Next, build a batch file to run your application. The batch file copies the codes from their file to the printer and runs the program in question (pray that the program does not have a printer reset hard-coded into its output routine). On returning to DOS, the batch file copies a printer reset code from another file to the printer before returning to the top-level applications menu.

Following the above logic, I loaded BASIC to build the necessary files—and the computer hung up. The dealer who sold my clients their new compatible system sold them genuine IBM PC-DOS to go with it. Great idea except that IBM BASIC hangs up non-IBM machines when it goes to load the kernel of BASIC from ROM, where it will not be found (so far as I know) on any non-IBM machine.

So back to the old system, a genuine IBM/XT. The command

```
PRINT#1,SPACE$(10) + CHR$(27) +
  CHR$(13) + "L"
```

should move the printer over 10 spaces and reset the left margin. Then, back to the new compatible system. Whoops, we need just one more space. No problem. Pull up the file in the text editor and add one.

Now, wait a minute. What's going on? All of a sudden, the printer is printing the "L" at the end of the escape sequence and not resetting the margin at all. What happened?

A quick check of file sizes makes me highly suspicious. The file with one more space in it has two more bytes than the previous version. Where did the second byte come from? The supremely helpful text editor converted the carriage return (ASCII 13) in the printer control sequence to a carriage-return/line-feed pair (ASCII 13-10). The printer was not amused. Back to BASIC, rebuild the file . . . success.

So let's review the bidding, shall we? All the user would have had to know to resolve the problem is:

- If the printer is producing readable text, even if it is only part of what you want, then the printer and cable are probably both all right.
- The left margin, page length, and other physical attributes of the printer and paper are logical variables that are software-controllable.
- ESC means "Escape" and is just another word for ASCII 27; CR is short for "Carriage Return," but really means ASCII 13; CR-LF is different from just plain CR.
- Batch files can copy strings from files to the printer before and after running an application.

Cocaine can make you blind.

Cocaine fools your brain.

When you first use it, you may feel more alert, more confident, more sociable, more in control of your life.

In reality, of course, nothing has changed. But to your brain, the feeling seems real.

From euphoria...

You want to experience it again. So you do some more coke.

Once more, you like the effects. It's a very clean high. It doesn't really feel like you're drugged. Only this time, you notice you don't feel so good when you come down. You're confused, edgy, anxious, even depressed.

Fortunately, that's easy to fix. At least for the next 20 minutes or so. All it takes is another few lines, or a few more hits on the pipe.

You're discovering one of the things that makes cocaine so dangerous.

It compels you to keep on using it. (Given unlimited access, laboratory monkeys take cocaine until they have seizures and die.)

If you keep experimenting with cocaine, quite soon you may feel you need it just to function well. To perform better at work, to cope with stress, to escape depression, just to have a good time at a party or a concert.

Like speed, cocaine makes you talk a lot and sleep a little. You can't sit still. You have difficulty concentrating and remembering. You feel aggressive and suspicious towards people. You don't want to eat very much. You become uninterested in sex.

To paranoia...

Compulsion is now definitely addiction. And there's worse to come.

You stop caring how you look or how you feel. You become paranoid. You may feel people are persecuting you, and you may have an intense fear that the police are waiting to arrest you. (Not surprising, since cocaine is illegal.)

You may have hallucinations. Because coke heightens your senses, they may seem terrifyingly real.

As one woman overdosed, she heard laughter nearby and a voice that said, "I've got you now." So many people have been totally convinced that bugs were crawling on or out of their skin, that the hallucination has a nickname: the coke bugs.

Especially if you've been smoking cocaine, you may become violent, or feel suicidal.

When coke gets you really strung out, you may turn to other drugs to slow down. Particularly downers like alcohol, tranquilizers, marijuana and heroin. (A speedball—heroin and cocaine—is what killed John Belushi.)

If you saw your doctor now and he didn't know you were using coke, he'd probably diagnose you as a manic-depressive.

To psychosis...

Literally, you're crazy.

But you know what's truly frightening? Despite everything that's happening to you, even now, you may still feel totally in control.

That's the drug talking.

Cocaine really does make you blind to reality. And with what's known about it today, you probably have to be something else to start using coke in the first place.

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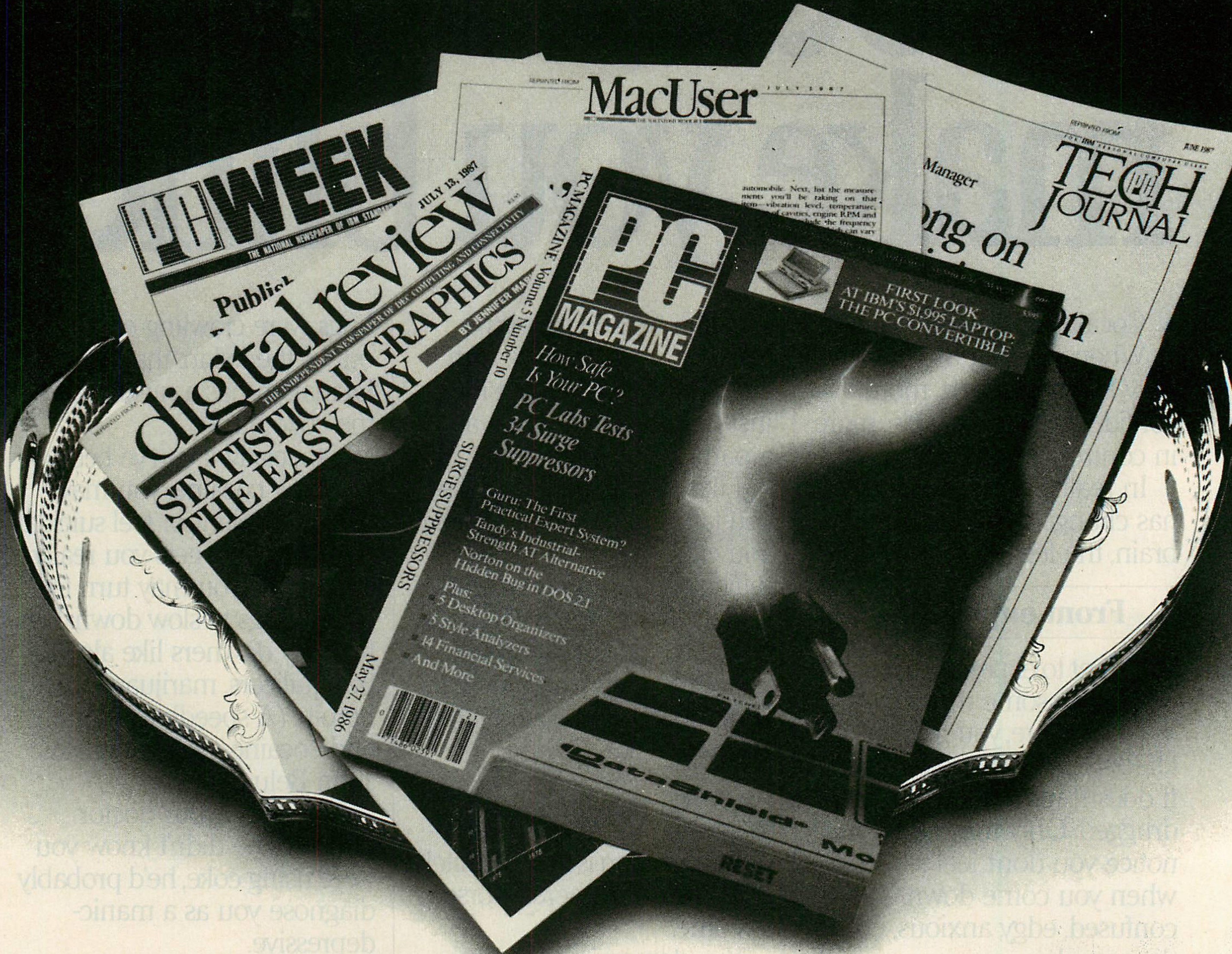

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- BASIC can be used to build arbitrary strings, once you learn to pretend that files are real.
- IBM BASIC makes non-IBM computers hang up.

This by no means exhausts the collection of guru-type knowledge required to deal with the trivial, day-to-day problems encountered when using PCs. You can call it expertise if you want to—I call it folklore.

WE ARE ALL IN THIS TOGETHER

There should not be any smug faces out there in Macintosh land, either; I have seen almost identical problems with the Mac. In one case, the printer kept telling the user "PostScript error: frameDevice," and the application would helpfully report, "The document is OK but cannot be printed."

That one was solved by going into the "native" Printer Setup screen. This required the user to bypass the application's private Printer Setup procedure by holding down the Shift key when making the selection from the menu (obvious, right?), going into the largely unknown Options screen under Printer Setup, and selecting the "Larger Print Area" option. Most Mac users do not even know this option exists.

A second, even simpler, incident involved a Mac that kept telling the user it could not even *find* the printer. I'm glad I wasn't the one who had changed the printer's network name over the weekend, appending the room number so people would know which printer was which when a second one was added to the network. Basically a good idea, but even the much-vaunted user-friendly Macintosh could not be bothered to say, "There is no printer with the name *X* on the net: please run *Chooser* and select another one."

Printing is not the only domain of such nonsense. I literally have lost track of the number of times that a user formatted an entire row or column of a spreadsheet, used only a fraction of its length or width, but ran out of memory just the same, because the program was too stupid to suggest that the blank formatted cells might not be needed. This, too, afflicts both the PC (Lotus 1-2-3) and Macintosh (Microsoft Excel) communities. Don't developers have any idea of what users do with their products?

FOLKLORE BREEDS FEAR

In a simpler age, folklore helped people cope with fear of the unknown by letting them think they knew what was going on. In the computer era, however, folklore convinces many intelligent people that using a computer is not worth the hassle. They know that when a problem arises, they may rack their brains for hours, or even days, only to find out that the answer was impossible to figure out. They just had to know it or know whom to ask.

Moreover, once most users have found something that works, they don't want to stick their heads out of the foxhole again to find something that works better. This results in early, spectacular productivity gains, then a quick and deadly stagnation. In Tom Peters's new book, *Thriving on Chaos: Handbook for a Management Revolution*, he sets forth the following as Prescription P-10 (the *P* is for people): "Eliminate Bureaucratic Rules and Humiliating Conditions." Peters wasn't talking about computers, but this should be one of the most important guidelines for designing and administering any computer-based system.

I am not talking about fantasies here, just simple courtesy. Let future releases of IBM BASIC return an error message, "This program requires IBM ROM BASIC," rather than hanging up the machine because you had the temerity to run it on someone else's hardware. Similarly, let error messages, in general, offer at least one likely suggestion about what might fix the problem—or at least a referral to a manual page that lists the probable causes of the error.

AND NOW FOR THE FOLLY

The main reason that computer folklore is such a problem is that the magic words vary so much from one machine to another. Learning one set of reasonably consistent conventions would not be so threatening to the casual user. It is therefore sheer folly to block the emergence of such standardization when it is the potential users' fear of long learning curves that holds back the growth of the market.

This brings us back to the Apple lawsuit. The target of my criticism has already provided the best possible attack. On page 344 of Apple CEO John Sculley's autobiography, *Odyssey*, he says: "If we sued our most important software supplier, our business customers would think we'd lost our minds."

Right on, John. You did, and we do. In one step, Apple went from being perceived with growing respect as the company that was showing how well things could be done, to being the company that did not have an encore and started throwing tomatoes at the other performers instead.

I see only two winners emerging from the resulting mess. The first is the group of users, including myself, who were thoroughly annoyed that the industry seemed to be waiting for Presentation Manager before it got serious about OS/2. With the new, intensified uncertainty over when Presentation Manager will be here and what it will look like, maybe developers will finally realize that at least 65 percent of what makes OS/2 important has nothing to do with the graphics user interface.

Wake up, developers. We are talking about virtual memory, multiple threads of execution within an application, dynamically linking libraries—in short, a collection of new capabilities that sounds more like Apple's promised early-1990s rewrite of the Macintosh operating system than like an imitation of Apple's current offerings.

The second winner will be the Smalltalk-80 implementors; they have substantial experience with a graphics-interface programming environment, which even includes multiple independent processes and has been licensed by Xerox for many years. Digitalk's Smalltalk/V, for example, though it does not implement the full language, still delivers a powerful development and applications environment for about the price of some products' runtime licenses alone.

Also in the ball game are ParcPlace Systems, whose Smalltalk-80 implementations are portable across Sun, Apollo, Hewlett-Packard, and Macintosh platforms; Softsmarts, with Smalltalk-80 for 80286 and 80386 machines; and Tektronix, whose 4315 workstation offers 5MB of RAM, an 86MB disk, and bundled Smalltalk-80 and C running under a variant of UNIX, all on a 68020 with 68881 math chip and all for less than $10,000 list price.

Tektronix also had the sheer marketing genius to bundle Insignia Solutions' SoftPC emulator with the 4310-series systems, providing PC emulation with XT-class performance in a window on the screen. Finally, you no longer need to keep a PC compatible nearby in order to run WordStar or Lotus 1-2-3 while your more powerful workstation sits idle. Having affordable hardware powerful enough to emulate a variety of mainstream systems has been a long-standing power-user's fantasy—it is finally a reality.

Plenty of developers, especially those delivering turnkey systems or in-house applications, would do well to examine Smalltalk-80 platforms as alternatives to the nonportable Macintosh operating system and the nonavailable OS/2 Presentation Manager.

The irony is that while today's affordable machines are finally crossing the critical line to become more computer than most users will ever need, development resources continue to concentrate on letting the user *do* more instead of making the machine *help* more. Those developers who take the lead in redressing this imbalance will be the first to get the business of the vast majority of potential users—the ones who have yet to buy their first desktop computer.

Peter C. Coffee is managing partner of SolveWare, a developer and business computing consultant, and is active in AI and distributed computing applications for aerospace and educational clients.

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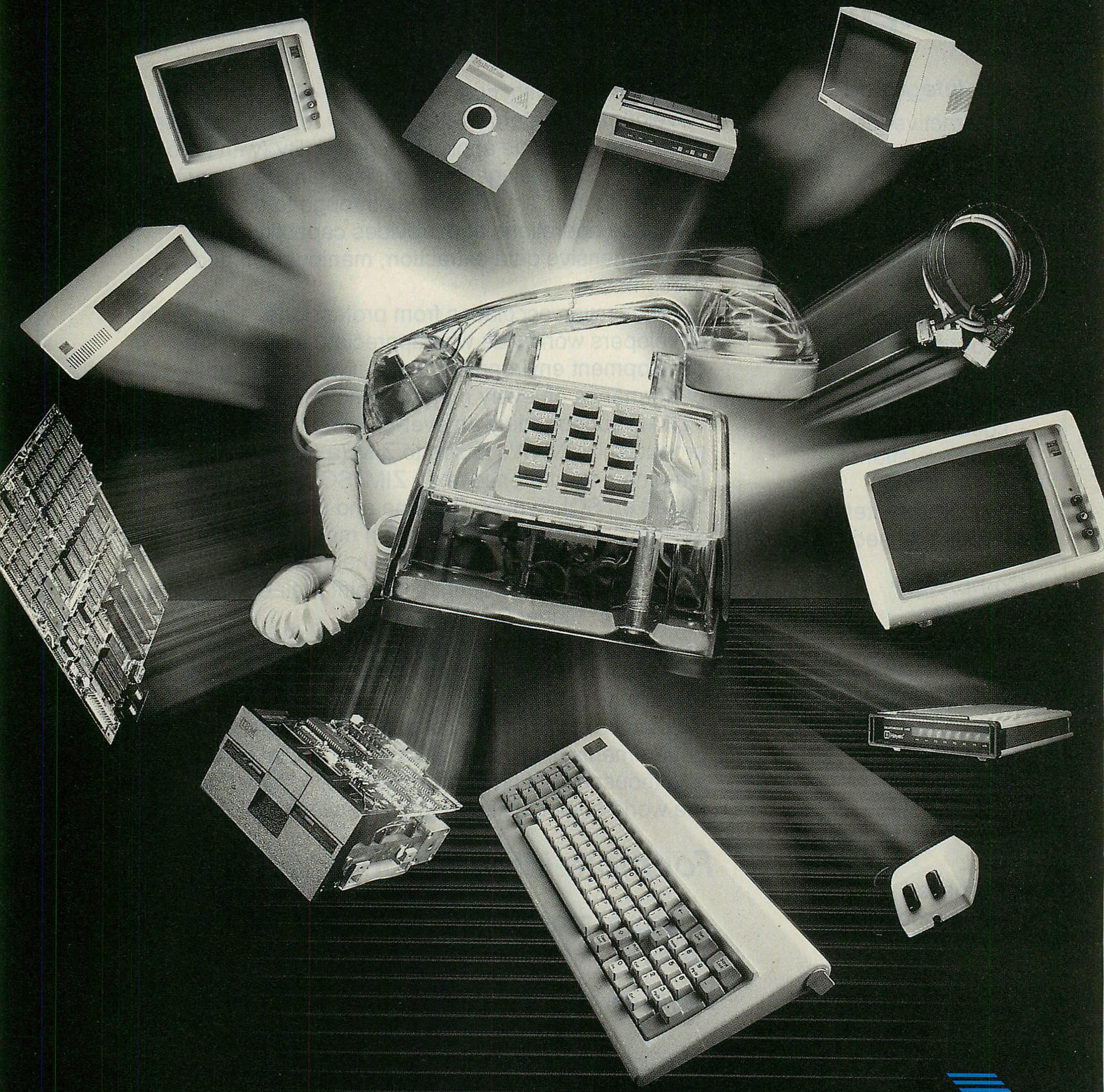

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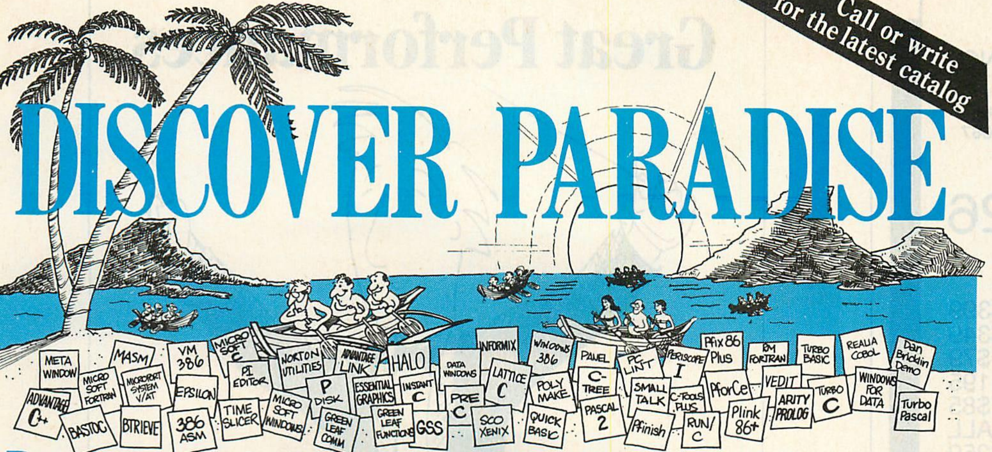

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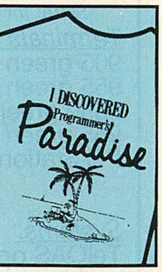

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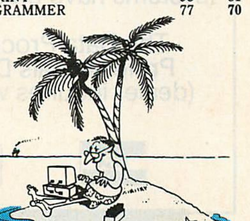

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PRODUCT CATEGORIES

HARDWARE 165, 166

ACCESSORY CARDS 165
COMMUNICATIONS 165
COMPATIBLES.............. 165, 166
COOLING DEVICES ....
GENERAL ....
MASS STORAGE ....
PERIPHERALS 166
SECURITY DEVICES..............
USED EQUIPMENT ....

SOFTWARE 166-172

ARTIFICIAL INTELLIGENCE ......
BUSINESS 166
COMMUNICATIONS 166
DATA BASE MANAGEMENT 166
DESK TOP PUBLISHING ....
EDUCATIONAL ....
ENGINEERING ....
EXPERT SYSTEMS ....
FINANCIAL.....................
GENERAL ....
GRAPHICS 166, 167
LANGUAGES 167
MULTI/USER SYSTEMS ....
NETWORKING 167
OPERATING SYSTEMS........... 167
PROGRAMMERS TOOLS 167, 168, 169, 170

SOFTWARE *continued*

PUBLIC DOMAIN.............. 170
SCIENTIFIC................. 170
SECURITY DEVICES 170, 171
STATISTICS....................
TERMINAL EMULATION 171
UTILITIES 171, 172
WORD PROCESSING..............

MISCELLANEOUS 172-173

ACCESSORIES ....
BAR CODING 172, 173
BUSINESS OPPORTUNITIES 173
CAREER OPPORTUNITIES.........
COMPUTER INSURANCE.......... 173
DATA CONVERSION 173
PUBLICATIONS 173
SOFTWARE DUPLICATION 173
SUPPLIES 173

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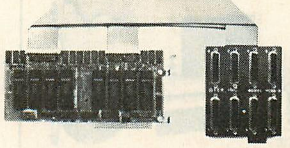

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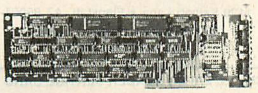

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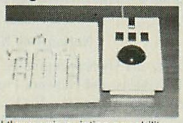

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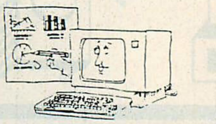

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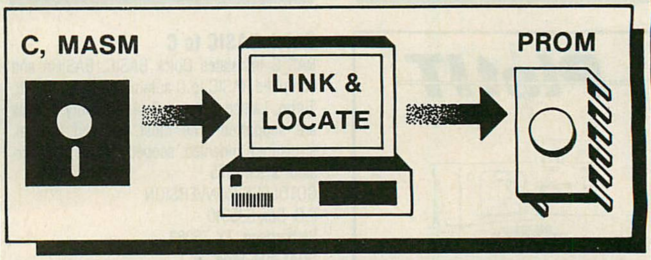

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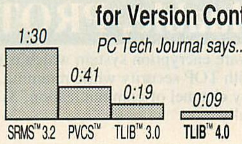

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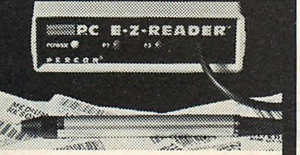

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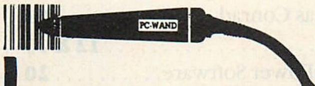

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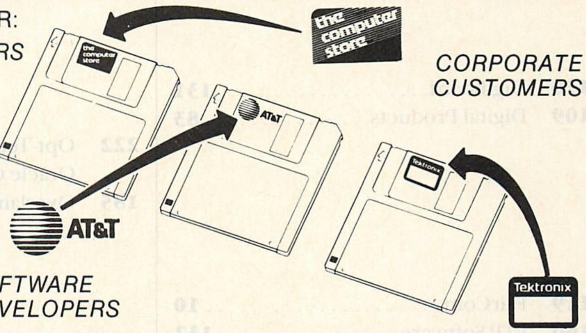

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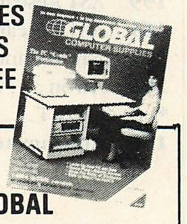

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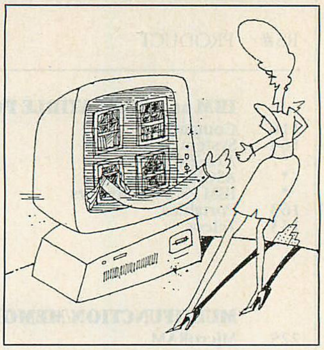
116	Advanced Logic Res.	Cover 3
253	AI Architects	152
*	Aker	26
131	Associates in Software	162
199	AST Research, Inc.	64
164	AST Research, Inc.	82
171	ATI Technology, Inc.	42 & 43
203	Atron	24
*	AT & T	31 & 33
165	Attachmate Corp.	118
102	Blaise Computing, Inc.	16
140	Businessland	50
124	Cadre Technologies	145
111	Catamount Corp.	133
122	Computerwise, Inc.	133
*	Creative Programming	151
167	Crosstalk Comm.	Back Cover
110	Digiboard	131
109	Digital Products	83
119	FairCom	10
160	FTP Software	132
139	Hammerly Computer	128
113	HavenTree Software, Ltd.	120
238	Hayes Microcomputer	48
*	IBM	97
*	IBM	74 & 75
112	IDEAssociates	134 & 135
108	Innovative Data Tech.	30
170	Innovative Technology Inc.	108
127	Lahey Computer	132
125	Lugaru Software	129
263	Mansfield Software	150
123	Matrix	93
259	MetaWare Inc.	119
211	Micro Data Base Systems	92
141	Micro Data Base Systems	94
*	Microsoft Corp.	53–56
*	Microsoft Corp.	80
*	Microsoft Corp.	141
*	Microsoft Corp.	Cover 2
*	MicroWay	163
174	Mortice Kern Systems	117
106	Multi Systems Devel.	154
224	Nantucket Corp.	121
201	Novell Devel. Div.	8
155	Nu-Mega Technologies	95
222	Opt-Tech Data Processing	4
*	Oracle Corporation	11
185	Overland Data, Inc.	108
233	PC Brand	136-138
114	Peacock Systems	105
215	Periscope Company	5
183	Peter Norton	129
144	Polytron	38
175	Programmer's Conn.	21
173	Programmer's Paradise	161
162	Programmer's Shop	14
161	Programmer's Shop	22 & 23
142	QMS	84
181	Quantum Software	68
137	Quarterdeck Office System	6 & 7
*	Raima Corporation	41
157	Rainbow Technologies	149
117	Santa Cruz Operation	62
*	SAS Institute	98 & 99
128	Saylors Softwarefirst	162
107	Scientific Endeavors	96
198	Seidl Computer	142
196	Software Link	73
189	Software Security	143
156	Solution Systems	109
130	Solution Systems	157
177	Stargate Tech.	158
152	Symmetry Group	27
154	Systemat	29
163	Tandon	110 & 111
225	Tecmar	19
143	TeleVideo	86
158	Thomas Conrad	91
129	TOPS	12 & 13
219	TurboPower Software	20
169	Venturcom	18
*	Vermont Creative Software	17
134	Versitron Inc.	28
132	WallSoft Systems, Inc.	148
213	Watcom	36
103	Wordtech Systems	66
136	XDB Systems	146
237	Zanthe Information Inc.	159

RS#	PRODUCT	ADVERTISER	PAGE
	IBM and COMPATIBLE PC's		
116	Compatible	Adv. Logic Res.	Cover 3
164	System 38L	AST Research	82
*	AT&T 6386	AT&T Info. Systems	31–33
*	ASCII terminal	IBM	97
*	IBM PS/2 Computers	IBM	74 & 75
163	Portables	Tandon	110 & 111
143	Teleos	Televidio Systems Inc.	86
	MULTIFUNCTION/MEMORY CARDS		
225	MicroRAM	Tecmar	19
	ACCELERATOR BOARDS		
112	PS 2 Boards	IDE Associates	134 & 135
*	Fast Cache 286	MicroWay	163
	MASS STORAGE HARDWARE		
111	9 Track Tape System	Catamount Corporation	133
108	FAME	Innovative Data Technology	30
185	9 Track Hardware	Overland Data Inc.	108
	PRINTERS & PLOTTERS		
142	Colorgrafix	QMS, Inc.	84
	INPUT SOFTWARE & HARDWARE		
122	The Transterm 5 Terminal	Computerwise, Inc.	133
	MODEMS		
171	2400 etc.	ATI Technologies	42 & 43
238	Smart Modem 9600	Hayes Microcomputer	48
	MICRO-MAIN FRAME/MINI COMMUNICATIONS		
165	Memory	Attachmate	118
	LOCAL AREA NETWORKS		
199	Ethernet	AST Research	64
140	LAN	Businessland	50
109	Net Commander	Digital Products	83
*	AT8	MicroWay	163
158	ARCnet Adapters	Thomas Conrad Corp.	91
129	TOPS	TOPS, Sun Microsystems Co.	12&13
	OTHER COMMUNICATION HARDWARE		
110	Open Ender Board	Digiboard, Inc.	131
177	ACL Board	Stargate Technologies	158
134	Fib. Op. Trans./Hub Concentrat.	Versitron Inc.	28
	COMMUNICATION SOFTWARE		
167	Crosstalk	Crosstalk Comm.	Back Cover
160	PC/TCP	FTP Software	132
170	Nita	Innovative Technology Inc.	108
	SCIENTIFIC/ENGINEERING SOFTWARE		
124	Teamwork/PCSA	Cadre Technologies Inc.	145
	LANGUAGES		
127	Lahey Fortran	Lahey Computer Systems	132
263	Personal Rexx	Mansfield Software	150
*	Pro Basic Intro	Microsoft Corporation	80
*	"C"	Microsoft Corporation	Cover 2
*	Fortran	Microsoft Corportation	141

RS#	PRODUCT	ADVERTISER	PAGE
	PROGRAMMER'S TOOLS		
203	PC Probe	Atron	24
102	Turbo C Tools	Blaise Computing Inc.	16
*	Vitamin C	Creative Programming	151
119	C-Tree, R-Tree	FairCom	10
139	ProBas	Hammerly Computer Services	128
113	Flowchart	HavenTree Software	120
125	Epsilon	Lugaru Software	129
123	Matrix	Matrix	93
259	386 Compiler	MetaWare	119
106	Screenmaker-T	Multi System Development	154
201	"XQL"	Novell Development Div.	8
155	Soft-ICE	Nu-Mega Technologies	95
222	Opt-Tech Sort, Scroll, Recall	Opt-Tech Data Processing	4
233	Programmer's Tools	PC Brand	136–138
114	CBTree	Peacock Systems Inc.	105
183	The Norton Editor	Peter Norton Utilities	129
144	PVCS	Polytron Corp.	38
198	Seidl Make Utility/Version Mgr.	Seidl Computer Engineering	142
156	C Worthy	Solution Systems	109
130	Brief	Solution Systems	157
152	"Keep Out" Slate System	Symmetry Group	27
215	Periscope	The Periscope Company	5
219	Turbo Professional Analys	Turbo Power Software	20
*	Windows for Data	Vermont Creative	17
132	UI Programmer	Wallsoft Systems Inc.	148
213	Watcom C for IBM PC's	Watcom Products, Inc.	36
	SOFTWARE UTILITIES		
154	Sortex	Systemat	29
	EXPERT SYSTEMS/AI SOFTWARE		
211	Guru	Micro Data Base Systems	92
	GRAPHICS SOFTWARE		
107	GraphiC & Vtek	Scientific Endeavors Corp.	96
	DATA MANAGEMENT SOFTWARE		
*	Magic PC	Aker Corporation	26
141	MDBS III	Micro Data Base Systems	94
161	Emerald Bay	Migent	22 & 23
224	Clipper	Nantucket Corp.	121
*	Professional Oracle	Oracle Corp.	11
161	Emerald Bay	Programmer's Shop	22 & 23
*	DB Vista, DB Query	Raima Corp.	41
103	Quicksilver	Wordtech Systems, Inc.	66
136	XDB	XDB Systems Inc.	146
237	ZIM	Zanthe	159
	OPERATING SYSTEMS		
253	OS/286 and OS/386	AI Architects	152
*	OS/2	Microsoft Corporation	53–56
174	MKS Tool Kit	Mortice Kern Systems, Inc.	117
181	QNX	Quantum Software Systems	68
137	API Tools	Quarterdeck Office System	6 & 7
117	Xenix	Santa Cruz Operations	62
169	Venix	Venturcom	18
	OTHER SERVICES		
*	The SAS System	SAS Institute Inc.	98 & 99
196	Lan Link	Software Link	73
	MAIL ORDER		
131	Televideo Products	Associates in Software	162
*	Mail Order	MicroWay	163
175	Mail Order	Programmer's Connection	21
173	Mail Order	Programmer's Paradise	161
162	Mail Order	Programmer's Shop	14
128	Software Products	Saylors Softwarefirst	162
	SECURITY DEVICES		
157	Software Sentinel	Rainbow Technologies, Inc.	149
189	The Block	Software Security	143

JORDENE ZEIMETZ

PROFESSIONAL VIEWPOINT



Graphics user interfaces mean more work for developers, but end-user benefits carry substantially more weight.

Say the words "graphics user interface" in a crowd of PC professionals and several people will say such devices are too cute, inappropriate for power users, and too slow for serious business applications.

Yet most *PC Tech Journal* readers responding to a recent poll (72 percent) say that graphics user interfaces are important for improving the applications they are developing; 28 percent see no advantage.

The contrast is due primarily to the different end-user audiences supported by these groups. Those in favor of graphics interfaces want a standard developed at the outset and are aiming at a broad target audience that finds icons and visual organization appealing and useful. Opponents, on the other hand, target power users who believe that icons and menus get in the way.

Supporters accept the added complexity and time required for development in exchange for a more palatable user environment, while critics resist learning new programming techniques, increasing development time and cost, and slowing execution.

THE GOOD

Major *user* benefits, say respondents, are ease of use, reduced training, fewer commands to remember, fewer errors, the ability to intermix pictures and text, application consistency, and lessened documentation dependency.

Respondents also credit graphics user interfaces with giving users a better sense of where they are in a system; promoting interactivity among users; aiding comprehension, productivity, and analysis; providing presentation-quality graphics; and improving the visibility and impact of data changes.

"The user is free to think about his own work, not the machine's; and that's what computing should be," says Philip Cain, consultant, Applications Design Inc., Chicago, Illinois.

Advantages cited for *developers* include ease in organizing applications and increased acceptance of PC applications by a wider market. William Lee, owner and president, Evolute Design and Development, Los Angeles, California, says, "We don't have to spend time developing a new interface, and we have easier access to graphics functions, allowing easier use of graphics and more useful text/graphics displays."

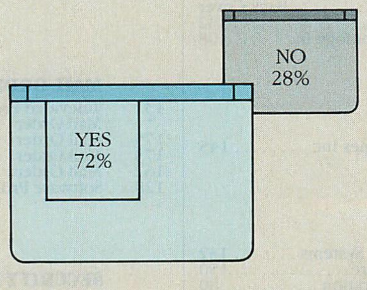
"Most important is graphically showing relationships between different database views, and allowing the user to select the appropriate view from the database icon," says Bradley T. Marshall, senior analyst, B. T. Marshall Company, Towson, Maryland.

THE BAD

Both supporters and opponents recognize the existence of problems, such as the need for more complicated code and hardware, increased work for developers, and the difficulty of establishing standards. Advocates believe these problems can be solved or that they are outweighed by the advantages.

Critics further complain that graphics user interfaces contribute to conflicts within applications, do not allow the developer to flag command files for multiple modes, make prioritizing batch processes difficult, reduce developer flexibility and innovation and cause them to focus on presentation over content, and act as an unwelcome barrier between the developer and operating system.

Could a graphics user interface improve the applications that you are developing?



Stressing the critical importance of a standard interface being applied consistently, Scott Whitmire, president of Advanced Systems Research Ltd., Renton, Washington, says, "If different applications use the interface differently, users could end up more confused than they are now."

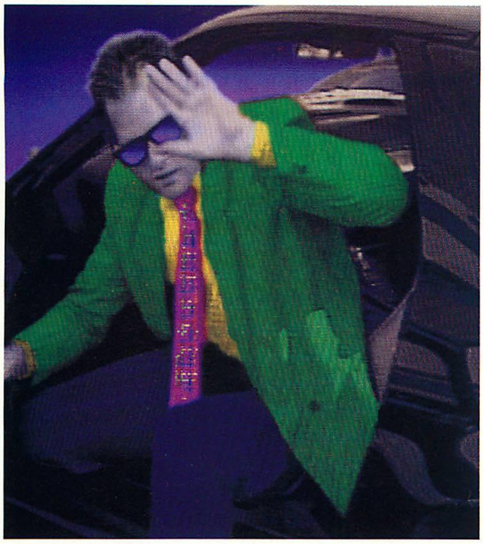
Developer reluctance to use a mouse and the extra hardware required (graphics subsystem, RAM, fast CPU, video memory, math coprocessor, and mouse) are other roadblocks to acceptance. "[A graphics user interface] limits your market to those who have graphics and mice—what about the typical user?" asks Bob Nance, consultant, NEWLIFE Software and Consulting, Clarksdale, Mississippi.

THE UGLY

A standard graphics user interface is well-supported by respondents, but many are concerned about the state of affairs as one evolves. "Until video-quality graphics are the standard, the graphics standard will be a moving target, thus a problem in development," says Joseph Sabin Jr., director of systems development, New Hope Communications, New Hope, Pennsylvania.

A standard will be better accepted if it allows developers and users to bypass the interface as desired and incorporates the mouse's pointing and cursoring ability into the keyboard.

The advantages of graphics user interfaces, however, do not come cheap. In addition to inflated RAM and CPU requirements, respondents say they expect higher application prices because of the extra time and complexity required for development.



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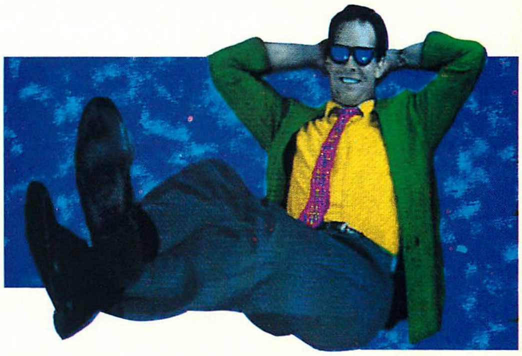

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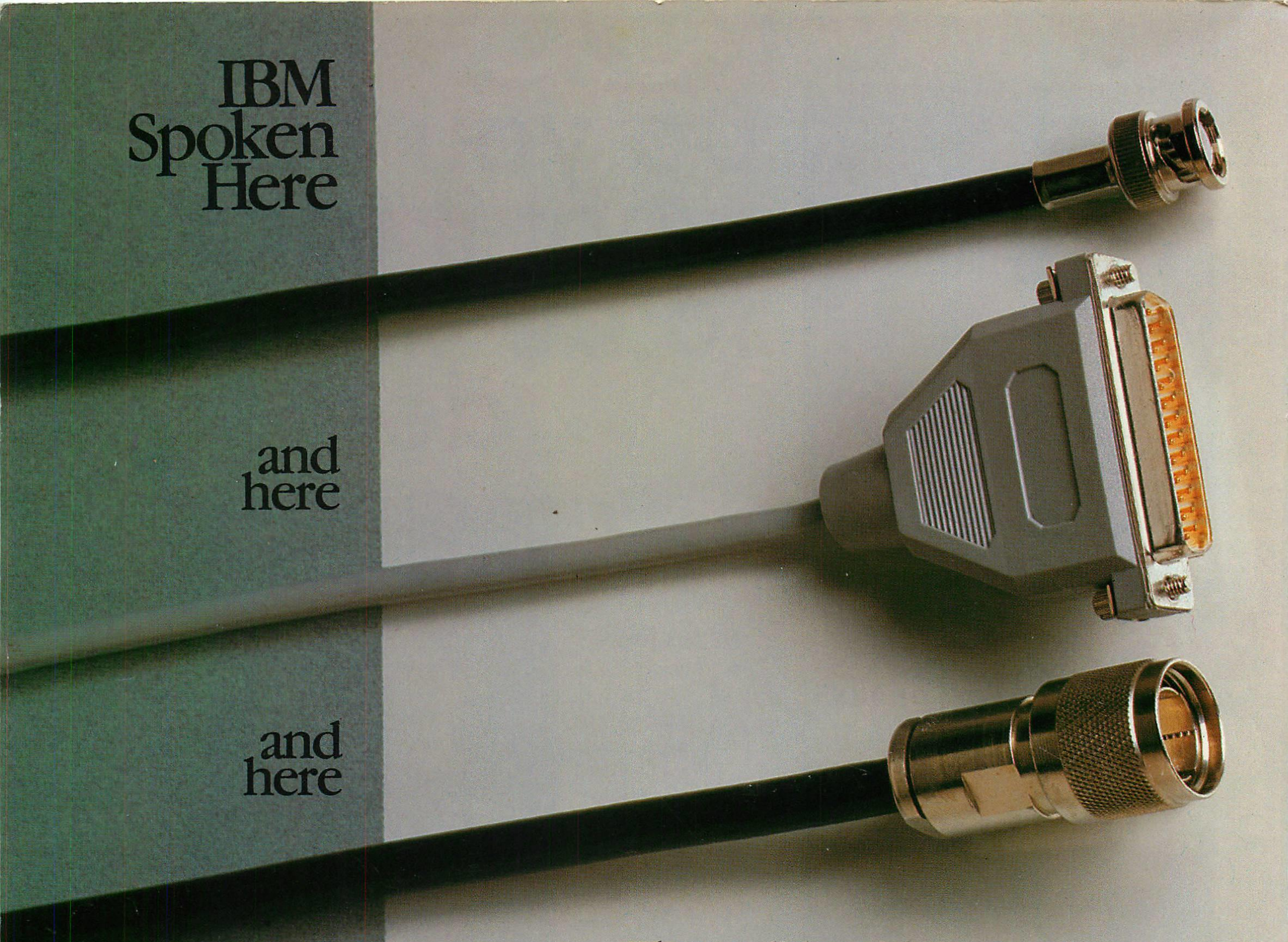

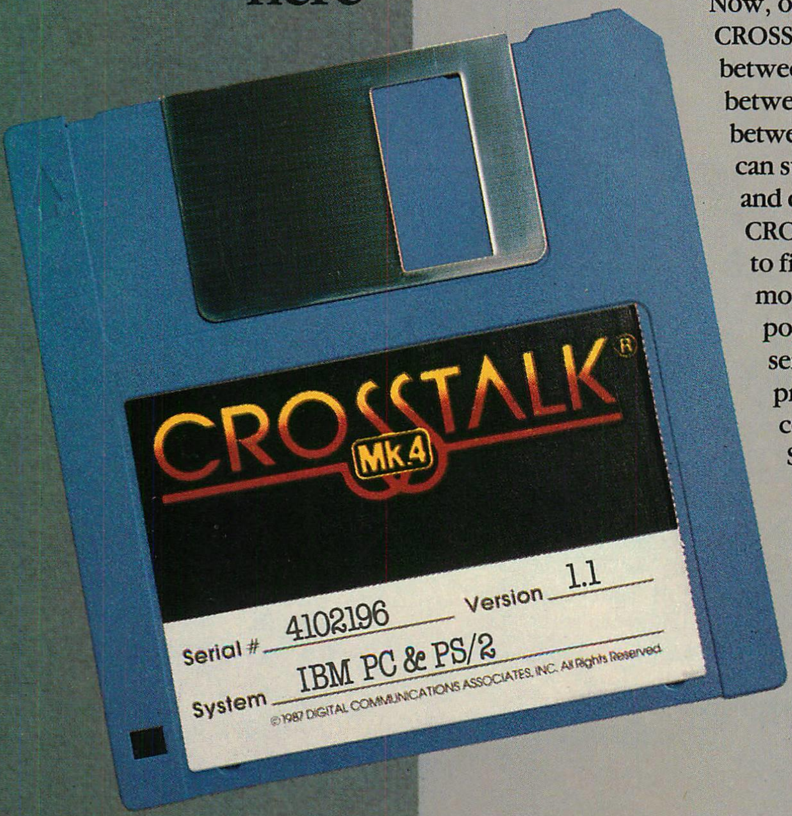

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